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Recent Advances in Steel Technology and Market Development

In producing this report, which has been compiled on the basis of contributions made by eminent experts in steel technology, the intention is to make available to those interested in steel from the commercial and essentially lay angle a straightforward account of some of the more promising developments, many of which are discussed in their broad economic setting.*

THIS report comprises four parts, dealing respectively with :—Ore preparation, coke-production, and blast-furnace practice ; steel-making developments ; rolling and finishing ; and recent progress in the technique of market development.

(I) ORE PREPARATION, COKE PRODUCTION, AND BLAST-FURNACE PRACTICE

(1) IRON ORE

(a) *Ore-Preparation Techniques* :—

The production of sinter as a means of using ore fines has been common practice for a great number of years. It has been generally recognized that sintering is probably the most satisfactory method of making use of the various fine materials and converting these into a suitable material to be charged into blast-furnaces. It is, however, only comparatively recently, particularly in the United Kingdom, that the use of sinter has grown rapidly, as is evinced by the fact that the annual production increased from 3·5 million tons in 1939 to 9·5 million tons in 1954.

This expansion has led to a completely new attitude to the sintering process. It has long been recognized that removal of the finer fraction of the furnace burden, both ore and coke, increases the permeability of the column of stock in the blast-furnace, facilitating blowing at a greater volume. The sintering of the fines before charging to the furnace used to be considered as an unfortunate necessity. It is now, however, widely recognized that good-quality sinter is a most desirable furnace burden constituent in its own right.

A further advantage of the sintering process is that the sulphur content may be reduced, thus permitting the use of a less basic slag in the furnace ; furthermore, the physical characteristics of the sinter are such that higher blowing rates may be maintained and higher blast temperatures used, yielding an improved output. The experience gained with a very high percentage of sinter in the burden leads automatically to consideration of the proposal to crush and sinter the whole burden.

This represents a complete reversal of the earlier theory that lump ore was desirable and fines undesirable. Burdens consisting entirely of sinter mean that ore-crushing plants must be arranged to crush all the ore to a maximum size suitable for sintering. Apart from the obvious question of the cost of additional crushing plant, the use of 100% sinter burden results in a change in operating responsibility.

(b) *Developments in Lorraine Ore-Fields* :—

French production of iron ore in 1953 amounted to 42·4 million tons, of which 39·5 million tons were produced in the Lorraine ore-fields. The Lorraine is, therefore, one of the largest iron-ore basins in the world. In addition to all the usual problems facing the extraction industries in general, the Lorraine ore-mining industry has certain difficulties of its own, among which may be mentioned such economic difficulties as the relatively low price fetched by the ore and the disproportion between the respective reserves of limey and siliceous ores. In the technical field, special problems arise in connection with seepage water and the fact that, as Lorraine ore is hard, dense, abrasive, and difficult to break, the machinery used must be very sturdy and hard-wearing.

(2) DEVELOPMENTS OF NEW COKING METHODS AND DIRECT REDUCTION

In addition to work proceeding in the Lorraine coalfield, the problem of producing metallurgical coke from coal other than typically coking coals is being approached in Western Germany by producing a material called ferro-coke.

Unlike ordinary coke, the grades of small coke arising in the production of ferro-coke cannot be disposed of on the general fuel market, but they can be economically gasified in smaller ferro-coke blast-furnaces. Moreover, large ferro-coke and a ferro-coke breeze made into lumps by various means can be used in large blast-furnaces.

Experiments have been in progress, steadily increasing the proportion of ferro-coke used and correspondingly decreasing the proportion of ordinary coke. A blast-furnace at the Friedrichshütte was operated with a 100% ferro-coke charge for a trial period of eleven days, which, though short, clearly showed that there is no serious difficulty in operating medium-size blast-furnaces on such a charge.

The furnace on which the trials were made had a daily production of some 180 to 200 tons of pig-iron and, in order to obtain comparable figures, the furnace was run on conventional metallurgical coke for a period of eight days before the ferro-coke tests ; in both instances the remainder of the burden was as nearly as possible similar. The only difficulty or noticeable difference with the ferro-coke was a tendency for the sulphur content of the iron to increase. It would appear from the results obtained that further development work in the use of ferro-coke in blast-furnaces is likely to prove interesting, though it must be remembered that, as the furnace used for the trials was comparatively small, it still remains to be shown whether ferro-coke can be efficiently used in a large, modern blast-furnace, where the weight of material and the height of the stack place far greater demands on the strength of the coke than those encountered in the experiment.

(3) PREREFINING OF PIG-IRON

The possibility of effectively prerefining pig-iron outside the blast-furnace is of value under many operat-

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ing conditions. If this can be achieved, the costs of the blast-furnace burden can be reduced and a better and more uniform product obtained.

(a) *Desulphurization* :—

As customers are continually demanding that the limit of sulphur content in steel should be brought lower and lower, the question of desulphurization before the steel-making process is gaining in importance. A further reason for desulphurization outside the blast-furnace is that the sulphur content of coke used for pig-iron production is tending to rise as increasing coke demand obliges the use of coals of inferior quality.

The method of desulphurization of pig-iron outside the blast-furnace developed in Sweden depends upon the addition of powdered lime in a rotary kiln. This addition makes it possible rapidly and effectively to reduce the sulphur content, even in cases where this is exceptionally high. The quantity of lime required for desulphurizing normally amounts to about 1% of the weight of the pig-iron, assuming an initial sulphur content of 0·1%. The desulphurizing treatment in the rotary kiln of approximately 15 minutes is usually sufficient to reduce the sulphur from, say, 0·1 to 0·01%. By increasing the duration of the treatment, or by increasing the quantity of lime, the sulphur content can be reduced to 0·005%. Pig-irons containing up to 0·5% or more sulphur can also be refined down to similar values, with a slightly increased duration of treatment and quantity of lime.

The most economical method of carrying out the desulphurization treatment is to use the kiln in place of the conventional ladle. The iron to be desulphurized is tapped from the blast-furnace direct into the kiln, which is then transferred by means of a crane onto the rotating mechanism where the treatment is carried out. After completion of the desulphurizing treatment, the kiln is transported to the steel plant, either for pouring as pigs or for transfer to a mixer. A complete separation of the lime is easily carried out during the pouring process.

(b) *Desiliconization* :—

The method adopted in the United Kingdom for desiliconizing outside the blast-furnace consists of the use of 30-ton transfer ladles, into which 20 tons of hot metal from an inactive mixer are poured onto graded limestone and a little fluorspar. A further quantity of limestone is fed in by hand while the ladle is being filled. Oxygen taken from an evaporator plant is blown through a lance into each ladle at 250 cfm for 20 min. The slag is then decanted and the metal taken to the open-hearth furnace. The hot metal has now had its silicon content halved, and is about 100° C hotter than unblown metal. This increases output and also reduces wear on steel-furnace banks and bottoms.

This method is suitable only where the metal can be treated in reasonably small quantities in an enclosed space. The gas can then be pumped into the metal quickly enough for efficient chemical usage, while at the same time the "slopping" which occurs when a high-silicon iron is treated with oxygen can be kept within bounds. Despite this quantitative limitation, a works in Western Germany desiliconizes about 80,000 tons per month of pig-iron for use in basic converters, using a 35% oxygen blast. The process was actually initiated for the recovery of vanadium, which is claimed to pay for the whole process. The ladles in which desiliconizing is carried out are of 30 to 40 tons capacity. About 200 cfm of oxygen are blown for 40 minutes through a water-cooled lance, the works' entire supply of oxygen being taken from a central "tonnage" oxygen generator.

(4) Special Types of Blast-Furnace

(a) *Low-Shaft* :—

The principal object of a low-shaft furnace is to find a means of producing pig-iron from coal of essentially non-coking quality and from fine ore. In other words, it is another aspect of that part of the problem dealing with fine ores which is being solved in large-scale production by the use of sinter in conventional blast-furnaces. It has been shown fairly clearly that the low-shaft furnace can in fact produce good-quality pig-iron from raw materials which would be unsuitable for use in conventional furnaces.

The success of the low-shaft furnace depends, however, to a very large extent on the proper and careful preparation of the burden, which consists essentially of forming briquettes from the two main constituents, i.e., fine ore and fine coal, with the addition of the necessary fluxes. It appears, however, that, although the problem of preparing the burden has been solved in small-scale production, it has yet to be shown whether it would in fact be economic on a large scale.

(b) *The Lubatti Process* :—

A new development which again seeks to solve the same problem of processing fine raw materials is represented by the Lubatti electric furnace developed in Italy. The Lubatti process is carried out in a furnace consisting essentially of a flat hearth with a refractory lining and one tap hole each for metal and slag. The top of the hearth is entirely open, i.e., the furnace itself has no roof. Furthermore, it requires neither a tilting mechanism as in the case of conventional arc furnaces nor any rotating mechanism as used in various other methods of ore reduction. The greater part of the furnace space is taken up by molten slag, which is heated by means of ball-shaped graphite electrodes dipping into the melt. These electrodes, one or two of which are connected to each phase of a three-phase electrical supply, are fitted to electrode holders at the sides of the furnace, thus permitting a free movement of the electrodes, both horizontally and vertically. The holders are water-cooled, on the same principle as for conventional arc-furnaces.

The burden, consisting of fine ore, is fed continuously onto the surface of the liquid slag in such a way that a layer of from 6 to 8 in. thick floats on the surface of the slag. The ore is reduced within this layer and the energy required for the reduction process is taken from the slag-bath, which has a temperature of about 1500 to 1600° C.

The carbon-dioxide gas generated during the process escapes through the layer of the burden, which, owing to the fact that it is comparatively thin, offers no appreciable resistance to the passage of the gas. Since the particles of the burden are small and thus have a large surface area in relation to their weight, the carbon monoxide is utilized for a pre-reduction within the layer of the burden. The gas escaping at the surface of the burden contains on the average twice as much carbon dioxide as carbon monoxide. It is claimed, therefore, that the energy contained in the coal is considerably better utilized than in the case of either the conventional blast-furnace or in a low-shaft furnace. The gas escaping burns away on the surface of the burden in the form of small flames spread over the whole area of the furnace top. It would appear to be possible to recover these gases, though this has not yet been attempted.

In the contact zone between burden and slag, the reduced metal is melted to form small globules, which then descend through the slag layer and collect in the furnace bottom. The furnace is then tapped in the usual way for both iron and slag.

(II) STEEL-MAKING DEVELOPMENTS

In recent years the bulk of steel production has been in Siemens Martin open-hearth furnaces and in basic converters, both of which have registered large increases. The production of acid Bessemer steels, which now represent only a small proportion of total production, has remained fairly constant. The manufacture of electrically melted steel, whether in arc-furnaces or by induction methods, has made considerable progress,

but has been mainly confined to alloy and other high-priced steels.

As regards steel-making, the outstanding difference between Europe and the United States is the higher rate of productivity achieved in the United States. The main reasons for this are excellent organization of the flow of materials, reduced repair times, larger furnaces, and better raw materials. The larger furnaces are mainly the outcome of the rationalization of American steel production, made possible by the existence of a huge single market.

(1) Open-Hearth Process

The open-hearth process still accounts for by far the greatest proportion of world steel production. During the past fifty years furnace capacity has risen from an average of 40 to 70 tons (1905 to 1925), 70 to 150 tons (1925 to 1935), up to 300 tons (1935 to 1955). Despite these great increases in furnace capacity, it is striking that the average time of heats from tap to tap has remained very nearly constant at 12 hours for the whole fifty-year period. This apparent lack of progress in tap-to-tap time can, however, be misleading, and it should be remembered that many old furnaces have been rebuilt and enlarged, so that production per hour has shown very great advances.

It would appear reasonable to suggest that, in future, the open-hearth plant should provide a substantially greater relative hearth area than those provided for in present practice. This is particularly important where a high percentage of hot metal is charged. A large hearth surface and shallower bath do not necessarily mean that the overall length of the furnace need be greatly enlarged, since, with the use of oxygen, the increased area can be provided by having smaller port and up-take areas. Provision should be made for the use of oxygen-enriched air, to permit rapid melt-down of scrap, and charging delays should be minimized.

(2) Duplex Process

Apart from the question of replacement of small-size furnaces by larger units, thus reducing the total number of furnaces in operation, it would seem that the time is ripe to give serious consideration to a major forward step in steel-making practice by the application of the duplexing process. Given suitable conditions, this process can bring about startling increases in production rates and reduce tap-to-tap time.

It is well known that there are considerable economic advantages in the practice of using ore additions when a high percentage of hot metal is charged in open-hearth practice. The main disadvantages are the time-consuming reactions involved and the critical requirements for proper flushing, so that the question arises of transferring these operations from the open-hearth furnace itself to a converter.

This is the origin of the Duplex system, which makes it possible to carry out the time-consuming operations rapidly and in a manner easy to control. The carbon, silicon, and manganese are eliminated in a matter of minutes in the converter, leaving for the open-hearth furnace, after the converter metal has been charged into it, the problem of meeting phosphorus, sulphur, carbon, and other specification objectives in the steel finally produced.

Open-hearth furnaces utilizing converter metal only can consistently produce heats in 3½ to 4 hr tap-to-tap time, which is equivalent to a rate of 50 net tons of ingots per hour for a heat-size of 180 tons. This represents a production rate of 2·5 to 3 times as fast as that possible from a similar sized open-hearth furnace employing conventional hot-metal charges.

This arrangement, however, has the disadvantage that it requires provision of open-hearth facilities to consume circulating scrap and cannot, therefore, be considered as a self-contained unit. Furthermore, the economies would be questionable of the use of the Duplex process on a self-contained basis, involving approximately 70% blown metal and 30% circulating scrap, since the production rates of tilting furnaces drop precipitously when high percentages of scrap are charged. In other words, the tilting furnace is not an efficient tool with which to consume appreciable amounts of scrap. However, this is not to the same extent true in the case of fixed furnaces, which benefit substantially when charged with blown metal, in any proportions, so that a modified Duplex process might well be considered.

(3) Bottom-Blown Converters

Future increases in steel production using the conventional converter processes are problematical. The outstanding advantages of the converter process are its low capital cost in comparison with the open-hearth process; its speed of melting, with the resulting advantageous rhythm of ingot pouring; and lower production costs, including in the case of Thomas converters the valuable by-product, basic slag, used as a fertilizer. Its disadvantages are mainly those of quality control.

Recent developments, particularly in a group of Belgian and Luxembourg steelworks, indicate clearly that a low-nitrogen rimmed steel can be successfully produced from high-phosphorus Lorraine ores in bottom-blown converters with varying types of enriched blast.

Nevertheless, as the basic difficulty of sampling blown metal remains, producers are compelled to fit the specifications to be rolled to the steel tapped rather than the other way round. The improved techniques of enriched blast have had the effect of increasing the percentage of charges which are suitable for conversion into specific end products of more exacting specifications, but they do not reduce the costs of selection.

(4) Turbo-Hearth Process

Some interesting developments resulting from the use of side- or surface-blown converters have led to the turbo-hearth process, which appears to have interesting possibilities.

It has been known for many years that, when a conventional converter is turned on its side and surface-blown, the temperature of the metal can be rapidly increased. In fact, it is common practice to use this technique if insufficient temperature develops during blowing. The fundamental reason for the generation of more heat with surface-blowing, as opposed to conventional bottom-blowing, lies in the fact that more of the carbon is completely burned to carbon dioxide within the vessel rather than at the nose of the converter.

One of the principal features is that surface-blowing, together with its associated turbulence due to the shape of the vessel and special blowing techniques, provides for a low nitrogen content in the neighbourhood of 0·002 to 0·003%. This nitrogen content is lower than for normal conventional bottom-blown converter steel. It is possible to visualize the use of the turbo-hearth converted for the production of low-carbon steels requiring good ductility, since the process produces such qualities very rapidly, compared with the open-hearth process. The turbo-hearth process is undoubtedly an interesting new field of development. It will, however, be necessary to await the results of further experience before its wider application can be contemplated.

(5) The "L.D." Oxygen-Blown Converter

It is claimed that the "L.D." process is capable of producing steels equal in quality to those of the open-hearth furnace but having in addition the advantages of the conventional converter process, i.e., rapid melting, advantageous rhythm of production, and moderate capital costs.

One of the problems in the operation of top-blown converters was the difficulty of removing the heavy brown fumes which result during blowing. Develop-

ments have been proceeding in Austria and a solution to the problem appears to have been found.

The waste gases leaving the converter are at a temperature of between 1700 and 1800° C. A waste-heat boiler has therefore been built into the stack, not only utilizing a large proportion of this heat, but also having the effect of lowering to about 500° C the temperature of the waste gases leaving the top of the stack. These cooled gases are then passed through a filtering unit, in the first part of which they are further cooled by means of water sprays; they are then led through turbulence tubes, to allow the fine dust particles to coagulate. In the second part of the filtering unit a further cleaning and filtering zone is provided, in which the dust particles, now coagulated to the size of ordinary blast-furnace dust, are cleaned. The final exhaust gases passing into the atmosphere have a temperature of not more than 30 or 40° C, and the collected dust deposited by the sprays and from the filtering unit is led into a settling tank. This is the basic principle employed, although, of course, a number of variations of method are possible.

(III) ROLLING AND FINISHING

Many detailed developments in rolling and finishing have taken place recently. Developments at Atlas Steels Ltd., Ontario, Canada, are of special interest, not only on account of the company's experience in continuous-casting operations but also because a hot-rolling planetary mill has been installed there for the reduction of continuously cast slabs into hot-rolled coils. A hot-rolling planetary mill is in operation in the United Kingdom, and though it has met with certain teething troubles, the decision by the Canadian company to install a mill of this type shows that it is regarded as having an economic future.

In the production of tubes, the stretch-reducing process, although not entirely new, has nevertheless assumed particular importance recently in connection with electric-resistance welded tubing. The stretch-reducing process consists essentially of a number of reducing rolls set in tandem, through which a tube is passed, each set of rolls reducing the diameter and stretching the material. In other words, it increases the length and at the same time reduces wall thickness. This development has assumed special importance, as the stretch-reducing mill enables a wide variety of tube diameters and thicknesses to be produced by ordinary electric-resistance welding from a standardized raw material. The obvious advantage of the process is that it permits the use of standard sizes of tube strip, leaving the stretch-reducing mill to produce the multitude of intermediate sizes required by the tube-using industry.

(1) Instrumentation and Control in Rolling Mills

The rapid expansion of the production of flat products brought about by the installation of wide-strip mills, in both the United States and Europe, has brought to the fore the question of adequate instrumentation and control. Until quite recently, the only instrument existing in strip mills to help the operator maintain the gauge of material was a flying micrometer fitted to the outgoing end of the cold-strip mill. This instrument showed whether the outgoing strip being rolled was above or below the required thickness. A press-button control then allowed the operator to adjust the screw-down gear accordingly. There was necessarily some considerable time-lag before setting alterations became effective, particularly with high-speed rolling mills.

A new range of mill instruments has recently been developed and among the most valuable are load meters for the accurate and continuous measurement of the load supplied to the rolls of strip mills; instruments for the measurement of strip tension; load and tension indicators; and indicating instruments for the measurement of gauge and for automatic gauge control.

(2) Continuous Casting of Steel Slabs and Billets

The outstanding advantage of continuous casting is the ability to go from molten steel directly to a semi-finished section. Continuous casting eliminates the need for all ingot-casting and stripping equipment, soaking pits, and cogging mills, which are among the largest and most expensive units in conventional steel production. An important further saving comes from a higher percentage of yield.

It may be confidently predicted that the use of the continuous-casting technique for all grades of special and alloy steels will advance rapidly in the near future, though for the production of bulk commercial grades of steel it appears unlikely that the conventional methods will be replaced for some time to come.

The latest type of continuous-casting machine has four operating levels and can cast slabs from $5\frac{1}{2} \times 7\frac{1}{2}$ in. up to slabs $5\frac{1}{2} \times 21\frac{1}{2}$ in. It is also capable of casting any size of billet over the general range of 4×4 in. to 6×24 in. The length of billets or slabs cast is limited only by the availability of hot metal; in practice, however, automatic oxygen-torches cut the continuous-cast slabs and billets into normal 16-ft lengths. The complete casting machine, with its framework and controls, weighs some 75 tons, but the vital water-cooled copper moulds weigh only from 500 to 1500 kg, depending on the size of the billet or slab to be cast. The weight of equipment therefore compares very favourably with that of an equivalent cogging mill and rolls.

(IV) RECENT PROGRESS IN THE TECHNIQUE OF MARKET DEVELOPMENT.

To be effective, technical progress must be applied fully in practice, and this involves active efforts to expand the market itself.

Comparison of market development in individual European countries and in the U.S.A. makes it clear that market development is in many ways less highly developed in Europe than in America. At the same time, however, much has been done recently in a number of European countries to promote both the development of markets for steel and the better use of steel. Nevertheless, it is stressed that much more can be done, particularly in the following directions :—

(1) The provision of greater resources for the conduct of effective market development in its many aspects, particularly at the company level.

(2) The establishment of closer working relations, particularly at the technical level, between engineers from the steel industry and the steel-consuming industries, to devise new and more economical ways of using steel; adjusting steel specifications, changing, where appropriate, designs in the consuming industry; or devising improved methods of production in the consuming industry.

(3) Detailed field enquiries on the relative merits of steel and other materials in specific applications, together with a wide dissemination of the results achieved.

(4) Wide application of standardization, both on national and international levels. Since a modern iron and steel plant can produce a wide range of products, there is a general tendency for each country to try to meet the whole range of requirements. There would appear, however, to be more scope for co-ordination of production programmes between producers in the same geographical area and thus greater specialization in the range of products manufactured. This, in turn, would tend to avoid over-proliferation of sizes and specifications.

(5) An adjustment of price structures, so as to provide adequate and proper incentives for the greater use of steel, particularly in new forms or in new ways.

Improved Radiographs by means of Tungstate Intensifying Screens

By F. Goos and T. Maas. (From *Schweissen und Schneiden*, Vol. 6, No. 11, November 1954, pp. 447-450, 3 illustrations.)

The investigation of materials, particularly welding seams, requires a maximum amount of detail in radiographic recordings, and considerable efforts have been made to fulfil this requirement. The actinic properties of heavy-metal salts, particularly tungstates, have been utilized to reduce exposure time and voltage, without altering the amount of detail which can be identified in the recording. It has been found possible to make further progress in the radiographic detection of defects mainly by improvements in tungstate screens (practically without any alteration of the intensifying effect), by better manufacturing methods, and by using fine-grain (silver-rich) films. The improvement is due not only to the higher contrast of screen and film, but also to the sensitivity of the film to the primary X-ray radiation, which is reproduced practically without scatter, and to its considerable sensitivity to actinic radiation, which is recorded more clearly and with less distortion by fine-grain films than by coarse-grain films. As a result of the combined effect of primary and transformed radiation, an insignificant reduction in definition and an increased sensitivity, in comparison with recordings without screens, are obtained.

The results of tests given in this report are limited to investigations of steel thicknesses not exceeding 40 mm and voltages up to 150 kV. A comprehensive series of tests, involving about 250 recordings, was carried out, the work being performed in all cases under similar conditions with an industrial radiographic installation of 150 kV for continuous-constant d.c. voltage, with a short-anode tube, focal spot 4 × 4 mm, and a film-to-focus distance of 700 mm. Metal cassettes were used in all cases, in order to avoid partial reduction in definition due to insufficiently close location. A lead sheet, 0·5 mm in thickness, was mounted behind the calcium tungstate screens to absorb back radiation, and lead sheets of 0·02 to 0·15 mm thickness, or, in some cases, sheets of tin, 0·5 mm thick, were used as stray radiation filters and mounted in front of the screens.

The " image quality " (expressed as a percentage of wire detail) was assessed by means of strips located close to the focus and by means of an aluminium step-wedge with iron-wire mesh behind it (wire thickness 0·3 mm). Darkening was determined by photometric methods and contrast by comparison with darkness scales (relative to dead black = 1). Detail indication depends on the degree of darkening :—Insufficient darkening produces a blurred film impression, owing to considerable light scatter, and also allows the grain of the film to show up in the film layer, thus breaking up contours and giving reduced detail. Excessive darkening affects the adjacent silver bromide grains so that, in spite of a higher contrast effect, by reducing and finally causing the disappearance of strip shadows, the image deteriorates.

Improvement in Detail

The value of a method for practical work depends not only on its sensitivity but also on its suitability for flaw detection. The detection of details, with normal darkening, depends on the combined effect of definition and contrast. Either of these factors considered separately is not decisive, and the image effect is due to the combination of both factors.

Undoubtedly, the assessment of image quality with wire strips is influenced by subjective criteria. Nevertheless, properly interpreted wire tests can serve for evaluations, when made under comparable conditions. It can be said that, with experience, these strips provide a useful basis for comparisons. Contrast and definition, although subjectively difficult to separate, are suitable for comparison by visual assessment of their decrease at boundaries or edges and from the degrees of darkening between a wire and its surroundings under different conditions.

Definition

Calcium tungstate (salt) screens, as compared with metal sheets, give reduced definition, owing to the transformation of the X-ray radiation pattern into luminescence. The secondary radiation generated in the metal and emerging from a relatively small depth through the practically homogeneous layer is subject to an insignificant amount of scatter with the radiation hardnesses under consideration, but it becomes more important for the luminescence generated in the tungstate screen by X-ray or γ-ray radiation. With luminescent materials, the reproduction of details is mainly determined by crystal grain and layer thickness. The optical reflection factor and the scattering properties of the carrier also play a part.

The influence of the crystal grain is frequently overestimated. Normally, its diameter is statistically distributed between 2 and 20 μ. Luminescent substances with particularly bright large-size crystallites have grain sizes up to 40 μ ; however, brightness and definition are reciprocal to each other. Various opinions have been expressed on the influence of crystal sizes on definition. It has sometimes been suggested that crystal dimensions are without influence, but this is not the case for diameters around 40 μ. Here, light scatter at crystal boundaries is clearly noticeable. On the other hand, the screen " grain " should not be overestimated for the usual diameters around 4 μ (and up to 20 μ). A further reduction in the already small size of the crystals will hardly lead to additional improvement.

Many attempts have been made in the past to use other substances in place of the tungsten salts now employed, but substances with a higher light-utilization factor or a more favourable spectral distribution, such as zinc sulphide or barium sulphate, cannot be considered in X-ray work for fine-detail screens. In particular, zinc sulphide has repeatedly been mentioned, but its intensifying effect is in any case considerably reduced at higher voltages and it has a number of serious disadvantages :—Light scatter in this material is much greater than in tungstates, the absorption of high-energy X-ray quanta is lower, and the afterglow, which is unimportant in tungstates, is frequently a disturbing factor. Moreover, zinc sulphide is sensitive to light and this can lead to discolouration and hence to a reduction in luminosity.

A much greater influence on image sharpness is that of the thickness of the luminescent layer of the screen combination, particularly of the front screen. With increasing layer thickness, light scatter on the crystallites, which are more or less densely packed and irregularly situated above each other in a large number of planes, becomes considerable. The " grain " sometimes observed in the image is in some cases erroneously attributed to a " screen structure." In fact, this can, in many cases, be explained (not considering scatter effects due to the irradiated object) by the greater contrast obtained in the reproduction of internal or surface inhomogeneities inherent in the object itself ; moreover, the grain of the film and its development also have some influence. A reduction in light scatter can be obtained by reducing the layer thickness and to some extent by suitable selection and colouring of the

bonding medium and the reflecting back surface of the screen. However, this frequently results in an appreciable loss of intensity, so that for each application a compromise has to be made between intensifying effect and reproduction of detail.

The scatter of the primary X-ray radiation in the screen, compared with light scatter, may be neglected. However, metal sheets, particularly with harder X-ray radiation (and γ-radiation), produce a scatter which is a function of layer thickness. This also sets a limit to the intensifying action. Soft secondary stray radiation is filtered out by absorption when using metal sheets; this is an advantage, compared with tungstate screens, since in this way, simultaneously with the intensifying effect, it is possible to eliminate a radiation which would cause deterioration of the image. However, by mounting lead absorbers or other suitable materials on both sides of the screen combination, this filtering effect can also be obtained with tungstate screens. It would even be possible to add a suitable metal filter directly onto the backs of the screens during manufacture. However, with the front screen, this filtering would have no marked effect on the quality of the image (in the range considered).

Contrast

As contrast is the second important factor influencing image quality, it can serve to compensate for some reduction in definition. With tungstate screens especially, the reproduction of the depth effect of the radiation occurs with much greater contrast than in the case of transformed radiation obtained with metal sheets. In most cases lead sheets produce a weak but sharply defined negative. In this respect, tungstate screens, with their high-contrast reproduction, have a major advantage. Thus, if it is possible to succeed in bringing the physically imposed reduction in definition to a minimum corresponding to the loss in brightness, then, by increased contrast, detail will be equal to (and in some cases even better than) that obtained with the metal sheet. The object of this investigation was to achieve this compensation. Tungstate intensifying screens of the "fine-detail" type, manufactured for specific requirements and commercially available, provide, together with normal sensitivity, a maximum amount of detail.

Influence of Film Grain

The effect of the screen on the X-ray film is to contribute in producing an image of adequate sharpness and maximum contrast. The widespread view that "screen grain" is much coarser than film grain is unfounded. On the contrary, film grain plays such an important part that it is worth considering more closely, since this factor offers a further possibility of increasing the quality of the image. In comparisons between metal sheets and tungstate screens, it is regarded as a matter of course in most cases that the usual highly sensitive but coarse-grained film sensitized for screen use should be employed with tungstate screens, whereas a non-sensitized extra-fine-grain film responding to electron emission is preferred for lead and other metal screens. Comparisons of this kind are bound to lead to conclusions more favourable for the lead sheet. The higher voltage or exposure time is then accepted as the cost of obtaining increased detail. However, with the recording technique indicated above, it is also possible to make use of the advantages of fine-grain films with tungstate screens, even if some of the intensifying effect obtained with the screen type of film is lost. In particular, films with a high silver content for "screenless" recording can be employed. The comparison shows that film grain has an effect which cannot be neglected. With very-fine-grain film and tungstate screens, it is possible to obtain such a definite increase in detail detection that the results cannot be bettered, even with lead sheets.

The normal screen type of film gives moderate

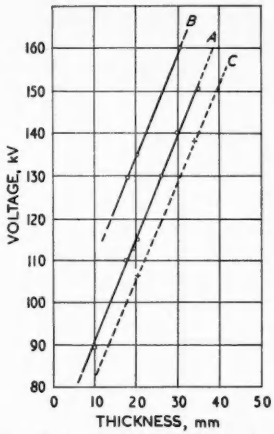

Fig. 1. Relation between steel thickness irradiated and voltage to be employed for a constant exposure factor (30 mA-min).

(*A*) Fine-detail screen with screenless-type (silver-rich) fine-grain film.
(*B*) Lead sheet (0·02/0·02 mm), with fine-grain film.
(*C*) Fine-detail screen with normal X-ray film sensitized to screen luminescence.

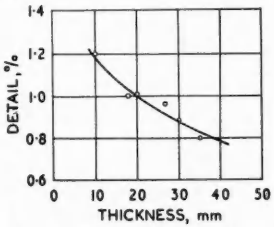

Fig. 2. Wire detail as a function of steel thickness for tungstate screens.

sharpness and a less pronounced edge definition of the strips, compared with fine-grain films. However, the improvement obtained with the same screen, using a screenless (direct or "non-screen") film, is evident, the detail limit being increased to 1% and edge sharpness also considerable improved. Finally, with very-fine-grain film for a 20-mm steel, the detail limit reaches 0·8% with a further increase in definition.

The screenless and metal-screen films investigated were far less sensitive than the screen type of film. However, with the use of lead sheets, the considerably increased exposure times or higher voltages have been accepted, so that, in employing fine- or extra-fine-grain films with tungstate screens, these differences should also be tolerable, particularly as in most cases much smaller increases are required than with lead sheets, in the range considered. If, however, it becomes possible to increase film sensitivity while still retaining the same sharpness, and particularly to sensitize the so-called screenless films or metal-screen films still further to screen luminescence, without deterioration of film grain, an advance in radiographic technique will be made.

Test Results

Fig. 1 shows that, in the range considered, the increased detail and definition obtained with the fine-detail screen and screenless film (*A*), compared with the more usual screen recordings (*C*), can be achieved by an increase of about 10 kV. The values for recordings of this type (*A*) are, however, still at least 20 kV lower than those of lead-sheet recordings (*B*).

(*Concluded on page* 298.)

The Nature of "Stark" Rubber

By D. E. ROBERTS and L. MANDELKERN. (From *Journal of Research of the National Bureau of Standards*, Vol. 54, No. 3, March 1955, pp. 167-176, 10 illustrations.)

FOR many polymers, including natural rubber, it has been observed that the melting temperature depends on the crystallization temperature when the heating rate is relatively rapid[1,2,3,4]. However, in the case of polyesters[2], polyamides[3], and more recently natural rubber[5], it has been demonstrated that, when slow heating rates are employed, the melting temperature observed is independent of previous thermal history and then the equilibrium melting temperature is approached. This heating schedule is presumably conducive to the formation of more perfect crystallites, which are stable at higher temperatures. For natural rubber the equilibrium melting temperature has been found to be 28 ± 1° C[4]. Melting temperatures appreciably higher than 28° C have also been reported for natural rubber. Considerable confusion has arisen, owing to the apparent variability of its melting point. Since the melting temperatures below 28° C have been demonstrated to be solely a result of the heating rates used in their determinations, the occurrence of melting temperatures above 28° C also requires explanation.

The natural-rubber samples which have been observed to have high melting points can be divided into two types, "racked" rubber and "stark" rubber. If unvulcanized natural rubber is repeatedly extended at an elevated temperature and then cooled, it can be given a rather enormous pseudo-permanent extension without any applied force being maintained[6]. Extensions as great as 10,000% have been reported. Rubber thus treated has been termed "racked" rubber, and its mechanical properties are similar to those of a hard inelastic material. The racking process is accompanied by an increase in density of the rubber, and its X-ray diffraction pattern gives a very intense fibre-type diagram, indicating not only that crystallization is occurring, but that the crystallites thus formed are highly oriented in the direction of the stretching. On heating, racked rubber retracts and the X-ray pattern disappears, indicating that fusion is occurring. The melting temperature, which depends on the extent of racking, occurs in the range between 35° and 50° C, which is substantially higher than the equilibrium melting temperature assigned to natural rubber. However, as the crystallites are highly oriented in racked rubber, the connecting amorphous regions must be deformed from their statistically more probable configuration, and hence the crystallites will be expected to be stable at higher temperatures than crystallites in an undeformed system.

When natural rubber is stored in temperate climates, it is occasionally found to be hard and inelastic, because of the development of appreciable amounts of crystallinity. Many of these samples also exhibit high melting points on initial heating, and this type of rubber has been designated "stark" rubber because it is hard and rather rigid at room temperature. Stark rubber has not until now been prepared under controlled conditions, and the reasons for its higher melting temperature cannot be ascertained from existing information, as in the case of racked rubber.

In an effort to understand the nature of stark rubber and the reasons for its high melting temperature, the melting behaviour and X-ray diffraction patterns of four stark-rubber samples, from widely different sources, have been investigated. As a result of this study some conclusions have been reached both as to the reasons for its high melting temperature and as to how it is formed. As a further consequence of these studies, methods have been devised for the laboratory preparation of stark rubber under controlled conditions.

The specific volume-temperature relations and the melting temperatures were determined, using dilatometric techniques. Descriptions of the volume dilatometers employed and the procedures followed have been published[3,7]. The dilatometers were immersed in constant-temperature baths, controlled within ± 0·1° C. The absolute densities of the stark-rubber specimens were determined at 25° C by the method of hydrostatic weighings.[8]

The samples for the X-ray diffraction studies were cut from the sheets of stark rubber into rectangular strips about 1 mm thick. The X-ray diffraction photographs were taken in a flat plate camera, using copper radiation (Kα) and operating at 40 kV and 20 mA. The sample-to-film distance was 10 cm, the aperture of the sample holder was 0·025 in., and the exposure time was 5½ hours. The variation in intensity of the diffraction around the circumference of a ring was determined by the manual use of a densitometer.

Sample I was a smoked sheet, prepared in 1913, and apparently similar to a specimen referred to in the literature.[6] Sample II was also a smoked sheet and had been highly milled, with the intention of using it as a rubber cement. It had been kept in storage between 1936 and 1951, when it was discovered to have become stark. Sample III, received in 1929, had been tapped and smoked, and washed and dried in Brazil. This sample was firm when received, but not as stiff as it became in 1952, when it was re-examined. Sample IV came from a bale of smoked sheet which had been kept in storage for several years; a portion of this bale was found to be stark, whereas other portions, including regions contiguous to the stark portion, were found to be completely amorphous.

The results of chemical analyses of samples I, II, and III showed that the amounts of the major constituents found are typical of the composition of unpurified raw rubber. Hence, it should be understood that the behaviour of stark rubber cannot be attributed to any major chemical differences from the usual, or normal, raw rubber.

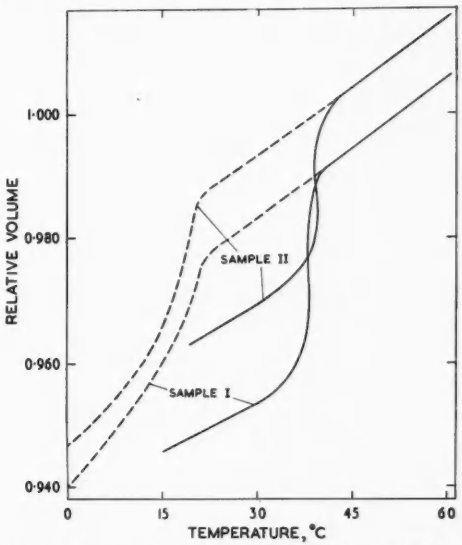

Fig. 1. **Relative volume-temperature plot for stark rubber.**
Solid lines: Original heating.
Dashed lines: Heating after initial melting and then crystallizing at 0° C.

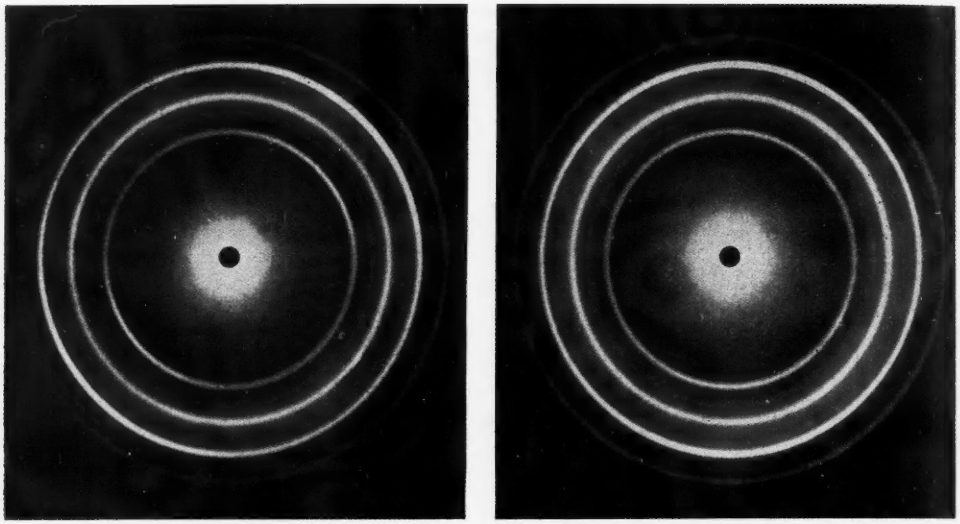

Fig. 2. **X-ray diffraction photographs of sample I, with** (left) **position of X-ray beam parallel to, and** (right) **normal to the plane of the rubber sheet.**

Results of Investigation

(*a*) *Melting Behaviour* :—

The melting behaviour of the four stark-rubber samples was investigated. Because of time effects above 35° C, a revision was required in the heating schedule. The observations were initiated at about 15° C, and the temperature was raised at the rate of 1° C each 12 to 24 hours. Up to temperatures of about 35° C, volume equilibrium appeared to be attained simultaneously with temperature equilibrium, and the specific volume varied linearly with temperature. This is in marked contrast with other polymers[3,5,7,9], in which partial melting and recrystallization always occur in the temperature range below the equilibrium melting temperature. At a given temperature above 35° C, the volume of the stark-rubber samples no longer remained invariant with time, but was observed to increase slowly. These slow increases in the volume of stark rubber in this temperature region have also been observed by Whitby[6]. Although the rate of volume increase was slow, the total volume change at a given temperature was significant. A typical example of this phenomenon is that, for sample I after 500 hours at 37° C, the specific volume had increased 0·0135 cm³/gm. After the temperature was raised to 38° C and held there for 240 hours, the specific volume had increased 0·00318 cm³/gm. Similarly, after 600 hours at 39° C it had increased 0·0030 cm³/gm, and after 500 hours at 39·5° C it had increased 0·0008 cm³/gm. These observations are also in marked contrast with the behaviour of other polymers for which, in the vicinity of the melting temperature T_m, only very slight increases in volume with time are observed. These observations for stark rubber necessitated the samples to be held for exceptionally long periods of time in the temperature interval between 35° C and T_m. In this interval the temperature was raised in increments of 1° C, and the sample was held at a given temperature until there was no perceptible increase in volume for about 5 to 7 days. Thus, the total heating process for a typical determination of T_m was of the order of 50 to 100 days. The melting temperature was then taken as the temperature at which the last trace of crystallinity disappeared, following the typical heating schedule just described.

The value observed for T_m will depend on the overall rate of heating and on the total time held at specified temperatures just below T_m. For example, sample II was initially held in the temperature range of 37° to 41° C for 26 days; T_m was found to be 41° C, and the total volume change in melting was 0·0250 cm³/gm. Another specimen of sample II was brought from 30° to 38° C in 7 days, and up to the present has been held at 38° C for a little over a year. A steady increase in volume has been observed, and 60% of the total volume change occurring on melting the first specimen has already occurred. There is thus the distinct likelihood that, if a sample of stark rubber is held at a temperature below the reported T_m for a sufficiently long time, a lower melting temperature will be observed[6].

Plots of the relative volume as a function of temperature are given in Fig. 1 for samples I and II. This figure also shows the curves obtained for the same samples after they were first melted and then recrystallized at 0° C. For the latter case the melting behaviour is similar in all respects to that usually observed for natural rubber. If stark rubber is first dissolved, and the solvent is sublimed or evaporated off, and if the sample is recrystallized at 0° C and slowly heated, the usual type of behaviour is also found[5]. Thus, if the crystallites originally present in stark rubber once disappear, subsequent crystallization induced by cooling is identical with that which occurs in ordinary amorphous natural rubber.

(*b*) *Melting Temperatures and Densities* :—

In Table I the specific gravities of the semicrystalline rubber ρ_{sc}; the completely amorphous rubber after melting the same samples ρ_a; and their differences $\Delta\rho$ at 25° C are given, as well as their respective melting temperatures T_m, which were determined from the specific volume-temperature studies. As the stark-rubber samples are almost identical in chemical composition, the variations in the density differences must reflect variations in the degree of crystallinity. The fact that the samples, when arranged in order of decreasing differences in specific gravity, as in Table I, are also in order of increasing melting temperatures, may be regarded as fortuitous, because the range of melting temperatures is only a little larger than the precision of determination. Therefore, the authors are of the opinion that the melting temperature does not depend on the amount of crystallinity.

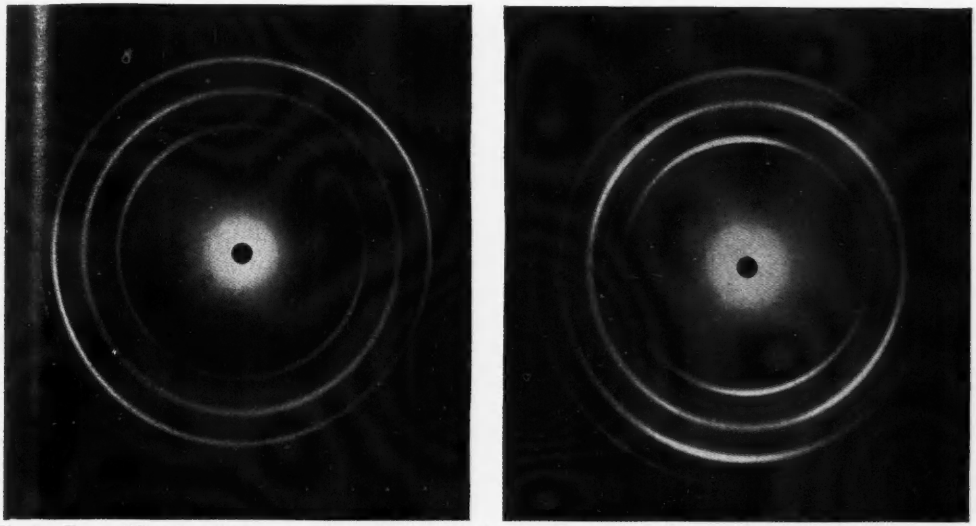

Fig. 3. **X-ray diffraction photographs of sample III, with** (left) **position of X-ray beam parallel to, and** (right) **normal to the plane of the rubber sheet.**

TABLE I. SPECIFIC GRAVITY AT 25° C AND MELTING TEMPERATURES OF STARK RUBBERS.

Sample	ρ_{sc}	ρ_a	$\Delta\rho$	T_m, °C
I	0·9405	0·9129	0·0276	39·5 to 40
II	0·9302	0·9094	0·0208	41
IV	0·9270	0·9092	0·0178	42
III	0·9114	0·8945	0·0169	45·5

(c) X-Ray Diffraction :—

Typical X-ray diffraction patterns (for samples I and III) are illustrated in Figs. 2 and 3. The positions of the four most intense rings correspond to the *d*-spacings given in Table II, and confirm the values given by Barnes[10] for stark rubber and that given by Clark, Wolthuis, and Smith[11] for rubber crystallized by either stretching or cooling. Thus, the crystalline form present in stark rubber is the same as that obtained on cooling amorphous natural rubber.

TABLE II. SPACINGS FOR STARK RUBBER.

d-spacing	Indices*
6·30	200
5·00	201
4·24	120
3·77	121
	121

*For a unit cell of dimensions *a*, *b*, and *c*, the direction of the chains (the fibre axis) is the *c* axis in the above.

An inspection of the X-ray patterns indicates that around certain of the rings the intensity of the diffracted X-ray is not uniform. This was seen most clearly in the pattern for sample III (Fig. 3) and sample IV. If the crystallites were randomly oriented with respect to a fixed direction in the sample, then the intensity of the diffraction should be uniform around the circumference of any given ring. The non-uniformity of the rings indicates that the crystallites have a preferred orientation in the sample. Further to confirm the reality of the orientation, a direction in the sample was fixed as reference, and the diffraction photographs were taken with the X-ray beam successively normal to and parallel to this direction. The results shown in Figs. 2 and 3 indicate that the diffraction patterns depend on the position of the beam relative to the sample, and hence the non-uniformity of the rings is caused by diffraction from oriented crystalline planes.

To illustrate these observations still further, variations in the relative intensity around the circumferences of the diffraction rings of interest were plotted. For all the samples the major variation in intensity occurred in the rings corresponding to reflections from the (200) and (120) planes, which are the only diffracting planes parallel to the direction of the chain axis. In sample II the effect was smaller than in the other samples, but the results are reproducible and well within the experimental limits of the photometering procedure. More than two diffraction photographs for each sample are required to establish the detailed nature of the orientation.

It is hoped that an analysis of the more detailed X-ray work now in progress will lead to a more quantitative description of the orientation. For present purposes, the establishing of the fact that the crystallites in stark rubber are oriented suffices.

LABORATORY PREPARATION OF STARK RUBBER

As stark rubber has not previously been prepared under controlled conditions, it is now thought possible to prepare it in the laboratory. Conditions should be sought such that the crystallization occurs while the rubber is being deformed, and that, when the external stresses causing the deformation are removed, the orientation will persist at temperatures above T_m. Carson[12] was able to produce stark rubber by deforming a sample in a rubber-cutting machine and storing under slight pressure for nearly a year at temperatures between 5° and 35° C.

Early attempts in this direction were made by Smith and Saylor[13], who compressed a sample of amorphous natural rubber between aluminium plates for 6 months at −25° C. The resulting crystallites displayed definite orientation, but the melting point was only 10° to 11° C. A further experiment was performed wherein the rubber was compressed in a steel block at a pressure of 1000 atmospheres and held at − 25° C for two weeks. On removal of the sample and on subsequent heating to room temperature, the rubber remained crystalline, and its melting point was found to be about 33° to 34° C.

About 1934, McPherson and Holt pressed some smoked sheet between aluminium-faced boards and then wrapped it very tightly with strips of stretched vulcanized rubber. Although the details of the thermal

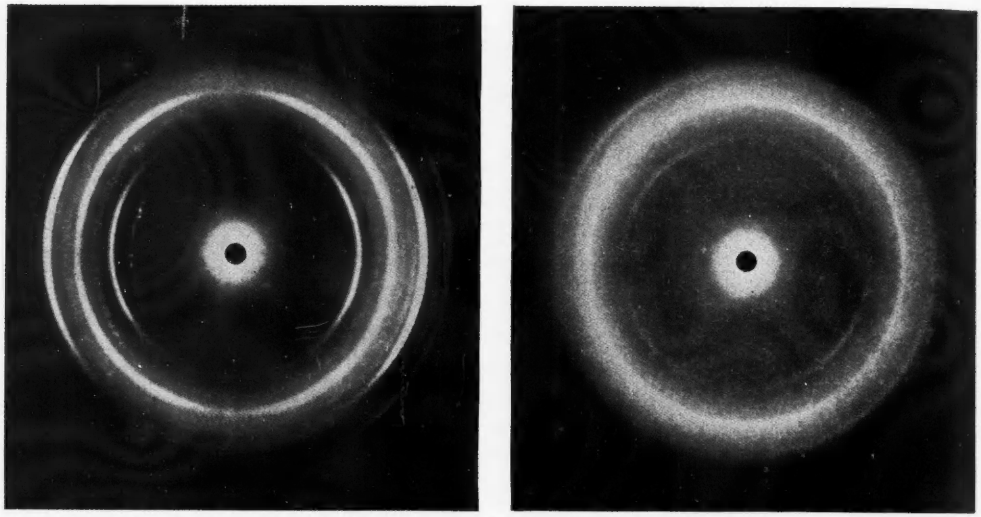

Fig. 4. **X-ray diffraction photographs of laboratory-prepared stark rubber, prepared by McPherson and Holt** (left), **and sprayed latex milled and rolled** (right).

history of the sample are not precisely known, the sample was kept most of the time in the temperature range of 0° to 14° C. The sample was examined in 1954 and found to possess an appreciable amount of crystallinity at 25° C. Dilatometric observations indicate that its melting temperature is greater than 35° C. In Fig. 4 (left), the X-ray diffraction photograph of this sample indicates very marked orientation.

A portion of a bale of sprayed latex, which contained about 95% of rubber hydrocarbon and whose X-ray diffraction pattern indicated it to be completely amorphous, was passed through a mill several times and rolled into a tight cylinder. After storage at 25° C for two years, it was re-examined and found to have lost some of its rubber-like elasticity. Its X-ray diffraction pattern is shown in Fig. 4 (right). Although the intensity of the diffraction pattern is not great, it is evident that the crystallites are oriented. Because of the small amount of crystallinity developed, the melting point could not be determined precisely, but it is in the range between 35° and 40° C. A portion of the roll was placed in a vacuum press at 28° C and subjected to a compressive load of 50 tons. The result of this treatment was further to increase the amount of both crystallinity and orientation. The melting temperature of this specimen is 42° ± 2° C.

A small section of cast-iron pipe, which was closed at the lower end and threaded at the upper end, was completely filled with the amorphous sprayed latex. The upper end of the pipe was closed with a threaded cap and tightened completely, thus subjecting the rubber to a compressive stress with orientation of certain regions brought about in the process of tightening the cap. After storage at 14° C for 18 months, portions of the rubber had crystallized. They maintained their crystallinity after warming to room temperature. The X-ray diffraction pattern clearly showed high orientation. The melting temperature was difficult to determine accurately, but is in the vicinity of 35° C.

Stark rubber can thus be prepared in the laboratory by a variety of methods. Those discussed above are certainly not exhaustive, and other methods should be equally successful. The essential requirement seems to be orientation during the crystallization. This is a necessary, but not a sufficient, condition. In the course of this study several methods attempted have not as yet yielded stark rubber. For example, holding samples at 14° C in simple extension at various extension ratios caused crystallization. However, when the tensile force was removed and the sample heated to 28° C, the crystallinity completely disappeared. Similarly, it is known from the work of Goppel and Van Rossem[14] that calendering rubber causes the crystallites formed on cooling to be oriented. However, when these experiments were repeated at the National Bureau of Standards, a completely amorphous X-ray diffraction pattern was obtained at 25° C. The difference between these results and those of Goppel and Van Rossem can be attributed to the fact that the diffraction photographs of the latter investigators were taken in the temperature range between 17° and 20° C. The apparent failure of the methods just described cannot be taken as final. It is possible that after longer times, when greater amounts of crystallinity have developed, the rubber may become stark by the methods outlined. Other laboratory methods of preparation are being explored.

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Procedure for Investigating Diesel Injection Sprays

By F. PISCHINGER. (From *Maschinenbau und Wärmewirtschaft*, Vol. 10, No. 3, March 1955, pp. 61-69, 9 illustrations.)

In the investigation described in this article, the procedure and its associated equipment were developed by the author from ideas due to Professor A. Pischinger. Taking account of the knowledge already available on continuous sprays, it enables further research to be made on intermittent fuel sprays discharged into a stationary or flowing medium.

ONE of the fundamental problems in the development of diesel engines is to obtain by suitable means the required mixture of fuel and air for the combustion process. It is therefore necessary to be able to observe the mixture formation directly.

The structure of a fuel spray depends not only on the shape of the nozzle but also on the other components of the injection system (injection pump and delivery pipe), as well as on the operating conditions (opening pressure of injection valve, quantity of fuel injected, and pump speed). These influences are reproducible in tests if the injection system used is the same as in the original engine. In addition, it is of interest to be able to examine spray formation in a vacuum, in still air, and with air movement in the spray chamber.

The process of mixture formation is influenced by the design of the combustion chamber (e.g., precombustion-chamber, swirl-chamber, or direct injection into a recess in the piston or the cylinder head). In the test rig, these features can be simulated to some extent, although simplification is necessary to permit observation and photographic recording of the events. Moreover, a pulsating air flow can be produced, but it is not considered essential, since in most investigations the period of mixture formation is so small that a satisfactory representation of these events can be obtained using a constant flow. The spray chamber was therefore designed to provide only stationary or steady-flow conditions. The required flow intensity, i.e., the flow velocity from moving to stationary portions of the combustion chamber, can be assessed by methods of calculation by Pischinger and Cordier previously published.

It was decided to avoid ignition of the mixture in these tests, since only that part of mixture formation which is not affected by combustion was to be studied. Consequently, for temperatures exceeding the ignition point, provision was made for nitrogen to be used instead of air, since nitrogen has physical properties similar to those of air for the purpose under consideration.

TEST INSTALLATION

The test installation consists of the injection system, the spray chamber, the air (or nitrogen) supply and flow-measuring equipment, and an optical system and photographic recording equipment. A schematic diagram of the test installation is shown in Fig. 1.

The injection system is similar to those normally employed in diesel engines. From the fuel tank (1) the fuel is supplied by a feed pump (2) through a filter (3) to the injection pump (4). The excess fuel flows back from the filter into the tank through the return pipe (5). Another return pipe (6) leads from the injection pump to the filter. The quantity of fuel delivered is regulated by a control knob (7), accurate adjustment being obtained by means of a micrometer screw (8). Actuation of (7) also causes release of a brake (9), which is adjusted to the delivery load. During the rest of the cycle, the brake is in contact with a flywheel, which is driven by an electric motor (10). Pump speed is infinitely variable and is registered by a tachometer (11).

The nozzle holder with a removable nozzle is fitted into a heatable insert (12), so that the nozzle can be heated as under engine operating conditions. The heating insert is fitted to the spray chamber (13). The length of the fuel line between pump and nozzle is important for the mechanism of injection and can be varied.

The spray chamber and the compressed-air (or nitrogen) equipment are also indicated in Fig. 1. The arrangement shown in this case simulates the conditions in the precombustion chamber of an engine. When operating with nitrogen, valve (14) is closed. From the bottles (15) the nitrogen passes through the pressure regulator (16), the stop valve (17) (the part permanently connected to the spray chamber being provided with a safety valve), and a heater (18) before entering the spray chamber (13). The chamber is subdivided into two communicating spaces. The right-hand portion represents the cylinder space and its pressure acts on the regulator (16), which, by means of this feedback, is able to maintain the precombustion-chamber pressure at its adjusted value by drawing the necessary amount of nitrogen from the bottles. The temperature of the nitrogen in the spray chamber is measured by a thermocouple and is indicated by a voltmeter (19).

From the " cylinder space," the nitrogen flows into the left-hand portion of the spray chamber, which represents the precombustion chamber, and the fuel is injected into this chamber. Pressure is measured by a pressure gauge (20) and the flow through the passage is determined by means of a differential gauge (21). The mixture is withdrawn through a cooler (22) in order to protect the regulating valve (23) from high temperatures. This valve maintains constant the pressure in the left-hand portion of the spray chamber. The corresponding pressure-control pipe can be ventilated by means of the three-way cock (24), in which case the pressure regulator (23) shuts off the discharge pipe.

The quantity of air flowing through the passages of precombustion-chamber or swirl-chamber engines (kg of air per second) is a multiple of the average weight of air per second aspirated by the engine (10 to 20 times larger). The arrangement described above makes it possible to limit the high flow of nitrogen to the short

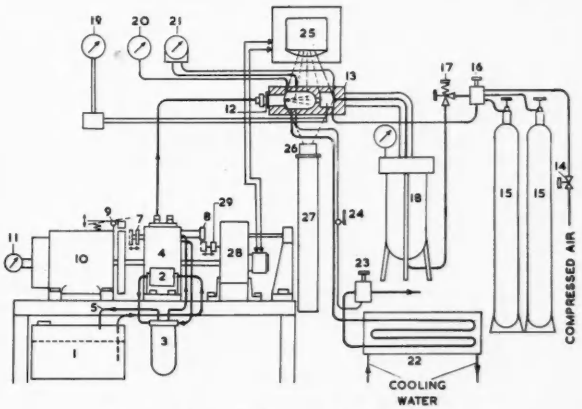

Fig. 1. Schematic diagram of test installation.

time interval required for photographic recording. By adjusting the pressures in the two chamber portions, i.e., by readjusting the preset values of regulators (16) and (23) before the test, flow conditions can be predetermined without using much nitrogen from the bottles. For the test, the installation is first put under pressure by opening the valves of the nitrogen bottles, pressure being controlled by the regulator (16). The flow is generated rapidly by actuation of the control (24) immediately before the photographic recording and the flow is cut off again afterwards.

For tests with fuel sprayed into still air or nitrogen, the second pressure regulator (23) can be replaced by a throttle which is adjusted so as to allow the fuel mist to escape from the spray chamber while maintaining the air velocity at a sufficiently low value to avoid any airflow effects on the spray. As regards the heating unit (18), in order to keep the amount of power required for heating to a low value, it is of ample capacity, so that the drop in temperature during the short duration of the test may be disregarded.

The spray chamber is illuminated by light flashes from a stroboscope (25) controlled by the camshaft of the injection pump. The control arrangement is such that the flashes occur with additive time lags of 1 deg. cam angle for each injection, so that the atomization process is recorded as a series of images, each of which is a successive phase of another injection. This procedure has the advantage of permitting low flash frequencies to be used. To obtain a similar set of photographs of various phases of a single spray, the frequency of the light flashes would have to be 361 times greater. The flash duration (3 to 10 microseconds) depends on the adjusted intensity. This apparatus was found suitable for the investigations.

By means of an optical system (26), the pictures are recorded on a film around the periphery of a drum camera (27), the movement of which is controlled by the injection-pump camshaft. The shutter is controlled by the injection equipment in such a way that only one picture is taken of each injection. The timing of the light flashes is obtained by means of a suitable transmission (28) and, by adjusting a suitable control (29), it is possible to illuminate either successive phases or always the same phase of the injection process. The latter possibility is useful in observing scatter, i.e., the variations in spray shape occurring in successive injections.

The injections were started only just before taking recordings, in order to avoid excessive blurring of the spray-chamber windows. It was found in the tests that, when the pump was started, stable conditions in the injection system were obtained even after the first injection. The photographs of phases of successive sprays include scatter due to variations in time intervals of the light flashes, as well as to the irregularities of the injection process itself. Investigations showed that the scatter in illumination intervals is extensively independent of frequency (i.e., pump speed) and does not exceed 18 to 24 microseconds. Consequently, any irregularity in the recordings which exceeded the variation corresponding to this value could definitely be attributed to the injection system.

Test Results

It is of interest to describe the results of some simple tests, so as to give an idea of the type of work that can be carried out with this test installation.

Injections into Still Air :—

The study of fuel sprays without the influence of air movement is essential for comparison of further work. The spray chamber and the illumination arrangement used for this purpose are shown in Fig. 2.

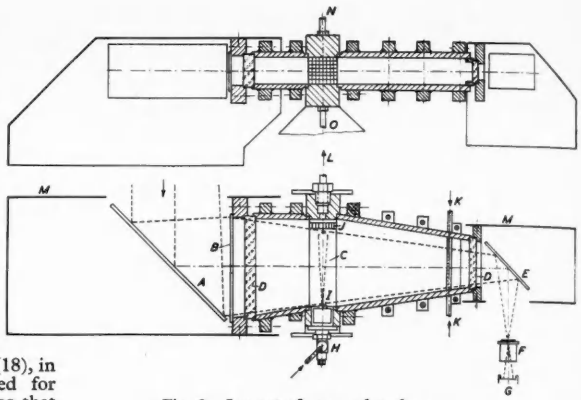

Fig. 2. **Layout of spray chamber.**

The light from the stroboscope is reflected by a mirror *A* onto a ground-glass plate *B*, which forms a background for the fuel sprays. The image of the fuel spray *C* is obtained through the glass window *D* by means of the mirror *E* and the optical system *F* on the film *G* of the drum camera. The nozzle holder *H* carries the injection nozzle *I*. Opposite this is a spray absorber *J*, which prevents rebounding fuel droplets from reaching the windows. The windows *D* are located away from the vicinity of the spray, so that they will not be covered too rapidly with fuel droplets. The fuel mist is removed from the chamber by a slight flow of air supplied at *K* and withdrawn at *L*. The mirrors were included for protection of the sensitive optical parts and the stroboscope equipment, and, for further safety in case of glass fracture, protective shields *M* were provided. The pressure gauge is connected at *N*. For spraying in a vacuum, the set-up is similar, except that the vacuum pump is connected at *O*, and a manometer at *N*.

Figs. 3 and 4 show typical spray photographs obtained with a pintle-type nozzle and a short-hole nozzle, respectively. The surface finish of the parts guiding the spray was of the usual commercial quality. The opening pressure of the nozzle was 130 kg/cm^2 and the quantity of fuel injected was 45 mm^3 per stroke for all tests. The pump speed was 1000 rpm, corresponding to a time interval of 0·166 millisecond (1 deg. cam angle) between successive photographs. The sprays were discharged into a vacuum, and also into air at ambient temperature, with pressures reaching up to 18 atm. At 20° C the fuel used in these tests had a specific gravity of 0·843 and a viscosity of 1·55° Engler or 6·08 centipoises.

The photographs of sprays at various stages of development serve to determine the depth of penetration and the velocity of the spray peaks. They also show the constantly varying discharge rates, which are due to oscillations of the nozzle needle during injection and to pressure fluctuations at the nozzle. In vacuum, where the spray is not slowed down by air resistance, the more rapid particles soon reach the peak, so that the rate of increase of spray length is higher than linear (Figs. 3a and 4a). The velocity reduction due to throttling is particularly noticeable with the pintle-type nozzle tested (Fig. 3a). The influence of air resistance causes a slower advance of the spray peak (Figs. 3b,c and 4b,c). The retarding effect of air is somewhat more marked with the short-hole nozzle than with the pintle-type nozzle.

It should be noted that the distance from the nozzle of the spray peaks, which are nearly completely slowed down by the air, varies by as much as 2 cm in individual injections. This is not due to time-interval variations in

illumination, since the scatter exceeds that of the light flashes determined in preliminary tests. The only possible explanation is that there are fine differences in the sprays emerging from the nozzle (nozzle discharge fluctuations) and that the influence of air resistance is therefore different on successive sprays.

In vacuum, where air resistance is non-existent, the spray pattern is determined only by the flow in the nozzle and the physical properties of the fuel. Hence, for a given type of fuel, the spray pattern in a vacuum is characteristic of the flow conditions in the nozzle used. Figs. 3a and 4a therefore show that the flow structure in the nozzle is continuously subject to fluctuations; these are due to reflection phenomena in the fuel pipe and corresponding oscillations of the nozzle needle. The fluctuations are clearly apparent with both nozzle types.

In Fig. 3a, the fuel emerges from the pintle-type nozzle as a compact spray. It widens out with secondary spray fronts at positions corresponding to the pressure-variation peaks, in particular after the first throttling stroke of the nozzle needle. In Fig. 4a, the peak of the spray from the short-hole nozzle is more loosely formed, and this may be attributed to strong turbulence during the bouncing of the needle. The first part of the following portion of the spray is then fairly compact, probably owing to considerable throttling at the needle seat. With subsequent fluctuations, the transverse components of motion reach such large values that the spray widens until it forms a hollow cone. The spray is divided into a number of streams or threads within the cone, in the longitudinal direction, so that it may be inferred that there is no continuous film of fuel. The film probably breaks up at the nozzle (this is not an "atomization," since a breaking up into minute droplets can occur only under the influence of air). The spray pattern is very different from that of the pintle-type nozzle.

Thus, the study of intermittent fuel sprays clearly indicates the features of non-stationary phenomena and shows why the results are not directly applicable to injection conditions in diesel engines.

A rigorously founded theory of the atomization of fuel sprays discharged at high velocity into air has not yet been developed. The most probable hypothesis is that of Castleman. According to this hypothesis, the effect of the air on liquid surfaces which have a high relative motion is that it causes liquid filaments to be torn off, which then, owing to surface-tension forces, are rapidly broken up into droplets. The filaments, according to Castleman, have a life of about 1 microsecond and are therefore below the limit of practical observations. Where the flow tends to form a large subdivided surface, the effect will be more pronounced and a more thorough atomization will be obtained. This is borne out by the present tests, which show that the pintle-type nozzle requires a more powerful air movement than the short-hole nozzle to produce optimum mixture forma-

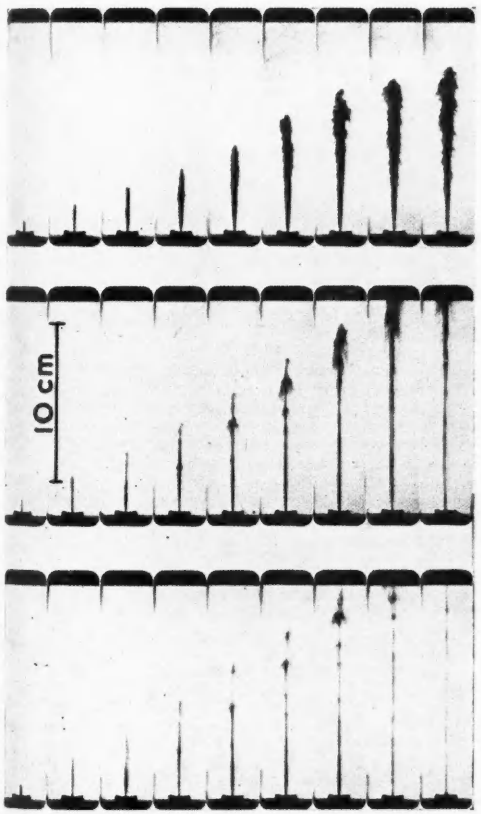

Fig. 3. **Sprays obtained with a pintle-type nozzle.**
(a) Into a vacuum (6 mm Hg).
(b) Into air at atmospheric pressure.
(c) Into air at 18 atm.

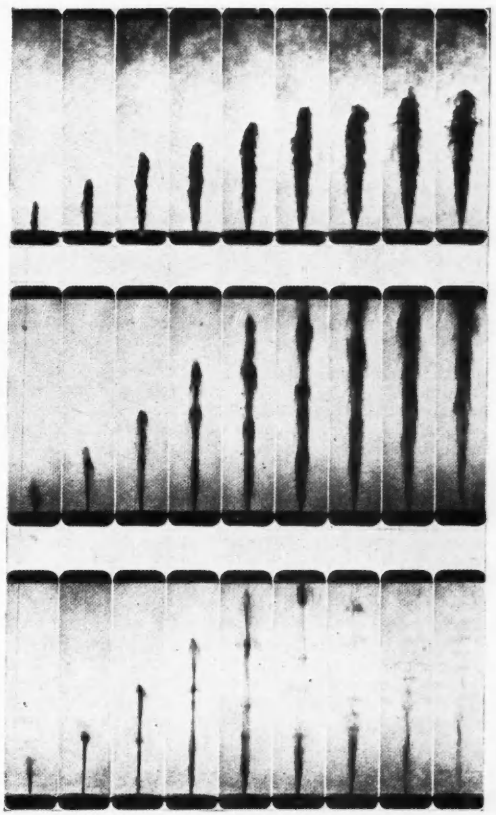

Fig. 4. **Sprays obtained with a short-hole nozzle.**
(a) Into a vacuum (20 mm Hg).
(b) Into air at atmospheric pressure.
(c) Into air at 18 atm.

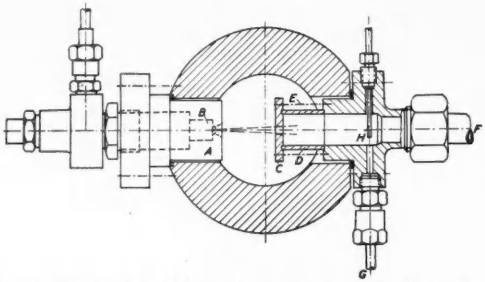

Fig. 5. **Cross-section of chamber used for spraying fuel into an opposing air stream.**

tion. On the other hand, the compact spray from the pintle-type nozzle has a greater penetrating power and will reach points situated at greater distances in the combustion chamber.

The photographs of sprays in air at atmospheric pressure (Figs. 3b and 4b) show that the wider or secondary-spray positions offer the best points of attack for the air to produce atomization. The outer areas of the spray, owing to the smaller fuel/air ratio, will be more rapidly decelerated than the core of the spray. Therefore, and also because of the varying structure of the spray in its longitudinal direction due to pressure fluctuations, it is possible to observe filaments of fuel mist pointing obliquely backwards in all sprays recorded with compressed air.

The spray photographs with the two nozzles show much smaller differences for sprays in air of high density than in vacuum. The more intense atomization obtained with the short-hole nozzle also becomes noticeable by the fact that the chamber fills up more densely with fuel mist, and this explains the darker background of the photographs in Fig. 4.

Fuel Sprayed into an Opposing Air Stream :—

The influence of air movement on the fuel spray can be shown by considering the conditions when a fuel spray is discharged into an opposing air stream. This case frequently occurs with precombustion-chamber engines. For the tests in the present instance, the precombustion-chamber boundary was omitted.

The spray chamber employed for these tests (Fig. 5) was designed on the same principles as the chamber in Fig. 2, except that it was given a circular (instead of a rectangular) cross-section. Opposite the insert *A* for the nozzle holder with the nozzle *B*, is situated a circular disc *C* with an orifice of 5 mm diameter and 5 mm in length. The glass-tube section *D* is made air-tight by means of the screws *E* on both sides. Air flows through *F* into the space formed by the glass tube, which corresponds to the cylinder space. The pressure in this section is transmitted through a pressure line *G*, and the temperature is taken by a thermocouple *H*, the resulting values being indicated by measuring instruments as in the test installation shown in Fig. 1. The air is removed from the spray chamber through a large number of small holes provided in the periphery of the chamber, immediately ahead of the glass plate on the stroboscope side (not shown in the figure).

For these tests, a pintle-type nozzle, with a release pressure of 134 kg/cm^2, was used. The quantity of fuel injected was 30 mm^3 per stroke, and the pump speed was 500 rpm. The temperature of the air in front of the orifice in *C* was about 22° C.

Fig. 6 shows the effect on the spray of the flow velocity through the orifice. Whereas, without air movement, the spray passes through the orifice unimpeded (Fig. 6a), a velocity of 121 m/sec in the orifice reduces to a small value the amount of fuel passing through (Fig. 6b). At an air velocity of 177 m/sec the spray can just reach the orifice (Fig. 6c), and at 220 m/sec the maximum length of the spray is considerably less (Fig. 6d). It is evident that air velocity has a marked effect on the atomization of the spray.

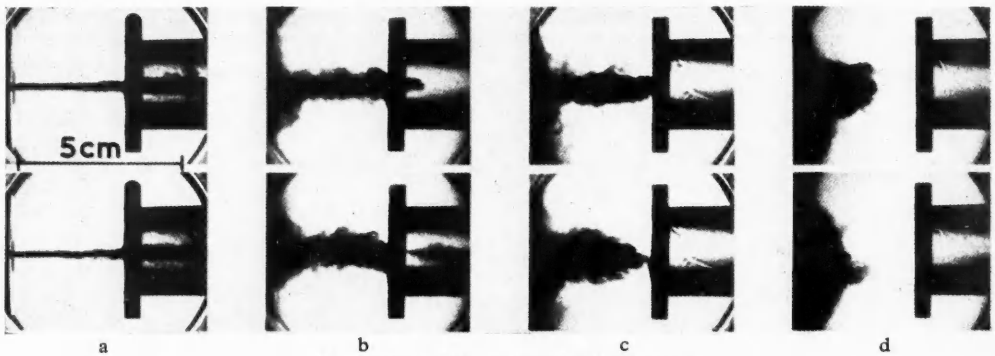

Fig. 6. **Sprays into an opposing air stream.**

(a) Chamber pressure, 12·1 kg/cm^2; velocity in orifice, 0 m/sec.
(b) Chamber pressure, 12·0 kg/cm^2; velocity in orifice, 121 m/sec.
(c) Chamber pressure, 12·1 kg/cm^2; velocity in orifice, 177 m/sec.
(d) Chamber pressure, 12·5 kg/cm^2; velocity in orifice, 220 m/sec.

From Fig. 6b it can be seen that the spray has a more compact core. Droplets which have already been slowed down by turbulent transverse motion in the air stream form a mantle with a large radial extension. At the end of the injection, if this mantle is no longer replenished from the core, it is blown back onto the nozzle. With increasing air velocity, both the decelerating forces acting on the core of the spray and the intensity of turbulence become greater. The spray mantle becomes broader and denser at the expense of the core, until the latter is no longer visible (Figs. 6c and 6d).

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Characteristics and Calibration of Bimetal Releases and Relays

By H. Haas. (From *Siemens Zeitschrift*, Vol. 29, No. 2, February 1955, pp. 61-68, 8 illustrations.)

Thermal releases and relays have a current-dependent characteristic, i.e., the time elapsing before actuation occurs becomes shorter with increased current. Such releases and relays are mainly of the fusible-solder, hot-wire, or bimetallic types. The latter, however, owing to their reliable operation and to the easy possibility of ambient-temperature compensation, are the most widely used. The bimetal strips can be of various shapes, differential thermal expansion of their dissimilar elements causing them to deflect (if they are held only at one end) or to alter their curvature (if clamped at both ends). The bimetallic members are heated either directly by a current passing through them, indirectly by means of a heating element, or by a combination of both arrangements, in which the heating element may be arranged in series or in parallel with the bimetal strip. In a.c. applications, direct or indirect heating is also obtained with current transformers.

Special current transformers are used where starting processes of motors require control over fairly long starting periods. In such cases, the transformer is designed to give a linearly proportional output up to about the nominal current. For higher values, the secondary current is reduced by saturation of the transformer iron. The reduced current from the saturated transformer requires more time to heat the bimetal member to its release temperature, and the control period is thus extended, as required.

The upper limit for operating temperatures of bimetal strips is generally around 150° C, with the strips heated to 115° above the ambient temperature of about 35° C. At certain positions on the strip, higher values may be reached, since temperature distribution is not uniform. With indirect heating, the temperature of the heating element may be even higher, reaching 200° C.

Bimetal members with direct heating respond after a fairly short time; with indirect heating the time lag is somewhat greater and depends on heat transfer. Since the strips are sensitive to heat, ambient temperature has an effect which is greater when the release temperature is low. To counteract this effect, it is usual to employ an additional compensating strip arranged in such a way that it will be affected only by ambient temperature; its action then opposes that of the main strip. With suitable design, the compensation is virtually accurate for ambient temperatures between 20 and 40° C.

The release current I_R is adjustable within certain limits relative to the nominal current I_N of an element, i.e., the maximum current indicated on the scale markings. For bimetal release devices, I_R/I_N can be varied from 0·7 to 1 and for relays from 0·5 to 1. Releases operate with fairly large forces and hence have a more limited range of adjustment than relays, which merely close or open contacts. The limit on the low side is set by the minimum deflection ensuring reliable operation, while on the high side the limit is based on the maximum permissible temperature of the unit. The required value of adjusted current I_A is obtained by altering the distance between the bimetallic strip and the releasing device, by means of a calibrated arrangement which can be common to all the bimetal strips in a unit.

Operating Characteristics

The operating characteristic is the curve giving the release times obtainable with various heating currents (Fig. 1), with the bimetal member in the "cold condition" (20° C) at the beginning of loading. The curves in Fig. 1 for relays (curve *A*) and releases (curve *B*) comply with requirements which specify that there should be no release within two hours when $I_R/I_A =$

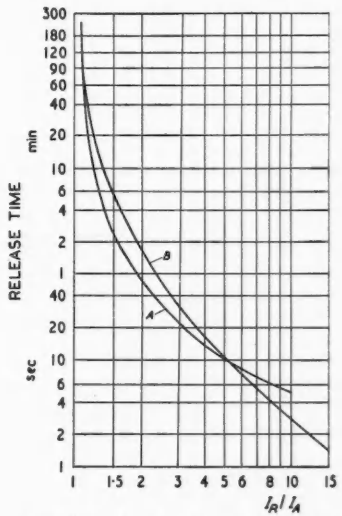

Fig. 1. Operating characteristics of a bimetal relay (curve *A*) and release (curve *B*).

1·05, whereas release should occur within two hours when $I_R/I_A = 1{\cdot}20$. The range of tolerance is therefore 15%, or ±7·5% on either side of a mean value. This mean value for two hours operation is termed the "limiting current." It may be noted that these remarks apply to the current; the tolerance relative to release time may be much greater than ±7·5%, particularly for low current values on the steep portion of the curve.

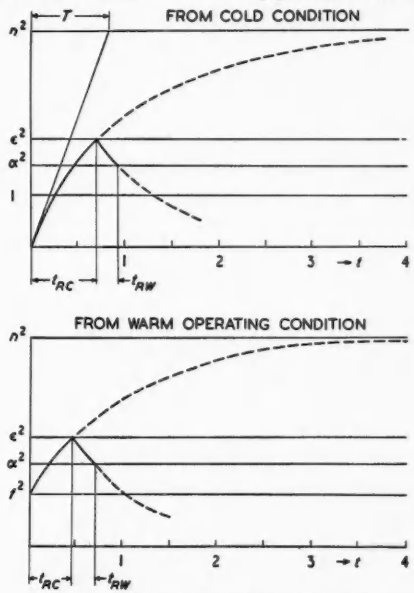

Fig. 2. Heating curves of bimetal strips.

The operating characteristic of a unit is generally valid for the case where all the bimetal strips are uniformly loaded. If, in multi-pole releases or relays, one or two bimetal strips are under reduced load or no load, the remaining elements are overloaded and may operate. Their response time will not then be in accordance with the operating characteristic. Moreover, the operative elements, being mechanically overloaded, will have a reduced deflection and hence require a higher temperature, i.e., a higher release current.

Where a unit is operating on reduced current shortly before reaching its release time, actuation may occur too early, owing to the heat flow from the heating element, which remains high even after the current has been reduced.

Effect of Working Temperature

The operating characteristics in Fig. 1 give the times required for release from the cold condition. When, owing to a preload current, the bimetal strip is required to operate from an initially warm condition, the release time is reduced. It is possible to determine this release time from initially warm operating conditions by means of eq. (3) below.

For simplicity, it is assumed that heating follows an exponential law and that the basic characteristic is the same, whether starting from cold or from warm operating conditions. The notation employed in Fig. 2 and in the equations to be considered is as follows :—

I_N = nominal current rating of bimetal strip ;
I_H = limiting current (2 hours operation) ;
ε = limiting-current ratio = I_H/I_N ;
I_P = preload current ;
f = preload-current ratio = I_P/I_N ;
t_{RC} = release time, from characteristic for cold condition ;
t_{RW} = release time, from warm condition ;
t_w = " off " time (time elapsing after release until the bimetal strip can be switched on again) ;
T = heating-time constant ;
I_L = load current ;
n = load current/adjusted current = I_L/I_A ;
θ_W = temperature of bimetal strip ready to begin operating cycle ;
θ_N = temperature of bimetal strip with nominal current ;
α = " off "-time ratio = $\sqrt{\theta_W/\theta_N}$;
A = $n^2 - f^2$;
B = $n^2 - \varepsilon^2$.

From Fig. 2, the release time t_{RC} from the cold condition is obtained as

$$t_{RC} = T \log_e (n^2/B) \quad \ldots \quad \ldots \quad (1)$$

and for the release time from the warm operating condition as

$$t_{RW} = T \log_e (A/B) \quad \ldots \quad (2)$$

so that

$$t_{RW}/t_{RC} = \log (A/B)/\log (n^2/B) \quad \ldots \quad (3)$$

This equation no longer contains the heating-time constant T, and gives representative values for all types of bimetal strips. Curves based on this equation, for the case of $f = I_P/I_N = 1$, are shown in Fig. 3. The ε-value can be taken from the operating characteristic for release after two hours, starting from the cold condition. In accordance with specified tolerance limitations, if the limiting-current ratio ε is taken as 1·12, Fig. 3 then gives $t_{RW}/t_{RC} = 0{\cdot}2$ approximately for large n-values ; in other words, the release time, starting from the warm condition, is about one-fifth of that starting from cold.

In most cases, $t_{RW} = t_{RC}$ for the limiting current, because, in the course of two hours, cold-starting and warm-starting conditions tend towards the same result. By means of Fig. 3, the operating characteristic from the

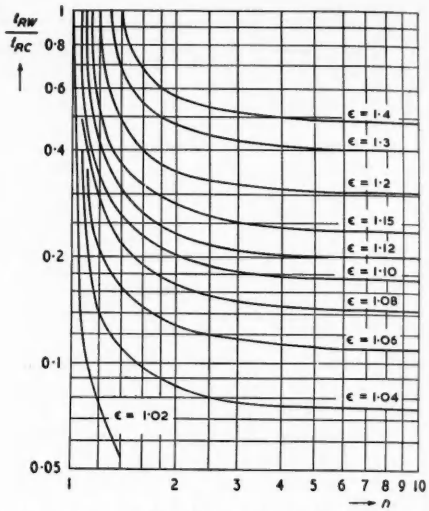

Fig. 3. t_{RW}/t_{RC} **as a function of** n **for different values of** ε.

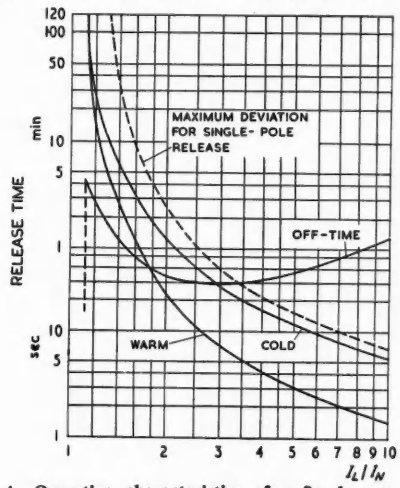

Fig. 4. **Operating characteristics of a 3-pole automatic switch with 200-A bimetal release, and maximum deviation for single-pole release.**

warm operating condition can be determined with a preload current equal to the nominal current ($f = 1$). Such a curve is shown in Fig. 4. Between this curve and the cold-starting characteristic are situated the curves of release times with various preload currents.

" Off " Time before Reswitching

The " off " time is the time elapsing until the bimetal strips have cooled down to such an extent that reswitching occurs with the contacts again in their original position. From Fig. 2, this reswitching time is obtained directly as

$$t_w = T \log_e (\varepsilon^2/\alpha^2) \quad \ldots \quad \ldots \quad (4)$$

Solving eq. (1) for T and inserting the result in eq. (4),

$$t_w = t_{RC} \log (\varepsilon^2/\alpha^2)/\log (n^2/B) \quad \ldots \quad \ldots \quad (5),$$

which is applicable to all types of bimetal strips. A curve of " off " time for $f = 1$ is also included in Fig. 4.

For bimetal devices, the off-time ratio α depends

on actuating force and actuating distance, while for bimetal relays it depends on contact force and type of contact operation. Representative values of α are :—

Bimetal releases :—1 to ε.

Bimetal relays, in which one contact is actuated slowly :—ε.

Bimetal relays with a short contact time :—0·7 to 1.

The reswitching time for any load current would be constant for a homogeneous body if its curve of cooling from the release temperature were strictly in accordance with the exponential law.

Overload Protection

The load to which bimetal strips are subjected is not unlimited on the high side. The maximum value of overload current up to which they can protect themselves by switching out depends on their dimensions and on the size of the heating element (if indirect heating is used). With higher load currents, the release time becomes shorter, but the heat accumulated in the bimetal device and particularly in the heating element is also higher, so that finally a temperature limit is reached at which either destruction of the heating element or permanent deformation of the bimetal strip occurs. For bimetal strips of normal types, this limit is at about 20 times the upper nominal current rating. To protect the bimetal elements, it is then necessary to connect them in series with either zero-lag quick-acting cut-outs or with fuses.

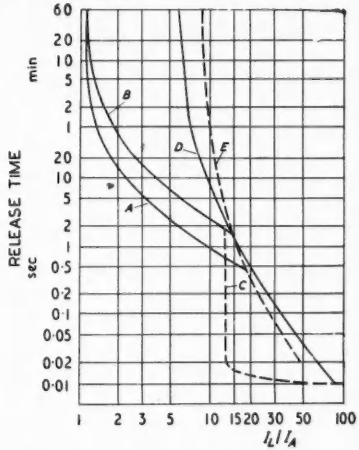

Fig. 5. **Protection of thermal release devices by means of quick-acting cut-outs or fuses.**

(*A*) Operating characteristic from warm condition.
(*B*) Operating characteristic from cold condition.
(*C*) Short-circuit quick-acting cut-out.
(*D*) and (*E*) Cut-out characteristics of two types of fuses.

When fuses are used, for adequate protection the limiting heat capacity of the fuse (its $\int I^2 dt$ value) must be lower than the heat value of current which would cause destruction of the bimetal strips. It should be noted that specifications for fuses generally give the melting time, the true switch-out time being greater, since it lasts up to the end of the extinction process. For fuses with melting times below 10 millisec, the extinction time should not be neglected ; if it is not known, it may be assumed to be about 5 millisec ; if the melting time is less than 5 millisec, the extinction time can be taken as being equal to the melting time. For this reason, the nominal current ratings indicated for fuses employed for the protection of bimetal strips should not be exceeded.

If cut-outs with quick-acting releases are employed, the cut-out ensures protection from the response threshold of its release mechanism. Hence, the bimetal strip will have to carry the short-circuit current during the cut-out time, which, on an average, is of the order of 20 to 40 millisec, depending on the size of the cut-out. The heat due to the short-circuit current during the cut-out time must be less than the heat value which would cause destruction of the bimetal strips. Consequently, quick-acting releases should not be set to values above the indicated release values or replaced by others set to higher values. Examples of the protective action of fuses and quick-acting cut-outs are shown in Fig. 5.

Influence of Ambient Temperature

By means of a temperature-compensating strip, the influence of ambient temperature on release time can be made negligible. However, it should be noted that, when the ambient temperature is above 35° C, although its effect on release action is compensated, the temperature of the main bimetal strip will reach correspondingly higher values for the same load current. Therefore, it is advisable in certain cases not to go to the full upper limit of the adjustment range. Although general recommendations cannot be made, since the reduction of load current for higher ambient temperatures depends on the thermal utilization of the bimetal device, which differs according to the application, some indicative values are given below :—

Ambient temperature	35° C	40° C	45° C	50° C
Upper adjustment limit, as a percentage of rated current	100	96	92	88

For devices without ambient-temperature compensation, the ratio p of the release current at ambient temperature θ_{AT} to the release current at an ambient temperature of 20° C can be calculated from the relation

$$p = \sqrt{1 - [(\theta_{AT} - 20)/\nu^2\, \theta_B]} \quad \ldots \quad \ldots \quad (6)$$

where ν = adjustment ratio = adjusted current divided by current at upper adjustment limit, and

θ_B = temperature of bimetal strip for release at the upper adjustment limit (usually around 150° C).

Calibration

To ensure that equipment is protected, every bimetallic release device or relay should be calibrated. Basically, there are two procedures, i.e., limiting-current calibration and overcurrent calibration.

Limiting-current calibration :—All the bimetal strips in a unit are loaded simultaneously. The leads used should have a cross-section which will ensure that all leads reach, but do not exceed, a temperature of 35° C under nominal current. Moreover, the leads should be arranged in such a way that no heating or cooling of the bimetal strips results from the leads themselves. The calibration is made for various divisions of the adjustment scale.

Overcurrent calibration :—Each bimetal strip is loaded from the cold condition with a multiple of the adjustment current I_A and adjusted so that its actuating time will have the specified value corresponding to the current I_R used. The corresponding values are based on characteristics of units of similar type.

In cases where bimetal strips have been replaced by others having a different nominal current, or during maintenance, it may be necessary to re-calibrate bimetal releases or relays outside the factory.

For such calibrations, it is convenient to employ a current transformer which can be adjusted on the primary side by means of a resistance, or a variable-ratio transformer. The calibration or check test is based on an operating characteristic or a set of calibration values. The current should be measured with an accurate ammeter and should not fluctuate during the loading period ; in addition, the equipment should be protected

from currents of air. If it is necessary to alter the release distances, this should be done without bending the bimetal strips. If bending cannot be avoided, the strips should be subsequently annealed at about 150° C for a period of several hours, so as to relieve internal stresses which might affect the release time.

Simplified limiting-current calibration :—The bimetal strips should be adjusted in such a way that they will not release at 1·05 times the adjusted value from the cold condition within two hours, although they will respond within two hours at 1·20 times the adjusted value from the warm operating condition.

For this purpose, all the bimetal strips in a unit are connected in series, using leads of adequate cross-section, and the load current should be equal to the nominal current of the unit. The first adjustment is to the mid-scale value and all the strips are set back so that they cannot trigger. The bimetal strips are then loaded for two hours with 1·12 times the current of the adjusted scale value. Thereafter, the current is raised to 1·4 times the adjusted scale value, without interruption. After 3 to 10 minutes (depending on whether the limiting current is to be situated nearer to the upper or the lower limit of the scale), the middle bimetal strip is adjusted so that it will cause release action. The unit is then allowed to cool down to ambient temperature ; this takes one or more hours, according to the size of the unit. If compressed air is used for cooling, it should be verified that the air is dry and that cooling is not excessive.

Next, without changing the current setting, the release time of the middle strip is measured at twice the adjusted scale value. When the apparatus has cooled down again, the other two bimetal strips are individually loaded with the same current and adjusted so that they will release after the same lapse of time as for the middle bimetal strip (with twice the adjusted current). The apparatus is then loaded at all terminals with 1·2 times the adjusted scale value. If the adjustment is correct, then the release device or relay should respond.

Owing to the variety of types of equipment, it is not possible to specify for all cases what the release time should be at 1·2 times the adjusted current. However, it may be stated that it should be less than 30 minutes. After calibration for the mid-scale value, the other scale values can be calibrated similarly, without further alteration of the settings of the bimetal strips. If there are deviations in release time with these settings, depending on whether the release times are too large or too small, the adjustment scale must be moved in the corresponding direction. After obtaining the same release time, a new calibration mark is inscribed.

Overcurrent calibration :—For this type of calibration, each bimetal strip is loaded individually from the cold condition with twice the value of the adjusted current and adjusted so that it will operate at a predetermined release time. The tests at each setting are carried out until the required release time is obtained without further readjustment. The release time is determined as the time required with single-pole loading from the cold condition, either on the basis of the makers' indications or by reference to a calibrated unit of the same type. If an operating characteristic is available, it can be used after taking account of the variation of the release current with single-pole loading. If neither reference data nor calibrated units are available, the equipment should be calibrated by the simplified procedure for limiting-current calibration.

Recording the Operating Characteristic

A prerequisite for recording the operating characteristic is that the nominal current (i.e., the highest permissible current for continuous loading) of the bimetal strip should be known. A convenient procedure is to connect all the strips in series and to set the adjustment scale to its mid-scale value. The load is then applied with 1·05 times the adjusted value for two hours ; no release should occur. The current is then raised to 1·2 times the adjusted value and release should occur within two hours. If release takes place in the first case, or does not take place in the second, re-calibration is necessary. The release time for 1·2 times the adjusted value already gives one point of the operating characteristic. The other points must be determined by successive measurements of release times at 1·3, 1·5, 2, 4, 6, and 8 times the adjusted value. The unit should be cooled down to ambient temperature after each measurement. The operating characteristic thus obtained is valid for uniform loading of all the bimetal strips. The limiting current is determined by drawing a vertical line through the point of the operating characteristic corresponding to a release time of two hours.

Calibration of Bimetal Relays used with Current Transformers

Before undertaking calibration of a bimetal relay used in conjunction with a current transformer, it is necessary to ascertain whether the two units match each other. Normally, this will be the case if the nominal current of the bimetal element does not differ considerably from that of the transformer secondary. If the ratio of the adjusted current of the bimetal to the current of the transformer secondary is not equal to unity, it should be taken into account, as well as the step-up ratio of the transformer itself. In this case, a special calibration of the transformer and bimetal relay is not necessary.

Where a saturated instrument transformer is used, however, the transformer should be calibrated together with the relay. If both are combined in a single unit, it may be assumed that matching is correct. If the transformer is external to the unit, the following measurements are necessary to determine whether or not it is matched :—

(1) The resistance of the bimetal strip should be determined ; this gives the power rating of the bimetal as RI_N^2, since the nominal current is known.

(2) The transformer, without the bimetal strip, is loaded on the primary side with its nominal current, and the secondary power output is determined for various load resistances by measurements of voltage and current. The power from the transformer secondary (in volt-amperes) should correspond approximately to the nominal capacity of the bimetal strip. If the nominal consumption of the strip is higher than the output power of the transformer, the release time will be too long ; in extreme cases no release action is obtained. If the nominal consumption of the bimetal strip is too small, release will occur too early ; in this case, matching can be achieved by connecting a resistance in series with the bimetal strip.

(3) Measurements should be made to determine whether heating of the transformer is still within permissible limits for the maximum release current in the range of release times considered.

The current ratio of the transformer is known from the measured results mentioned in (2) above. By means of this value, the operating characteristic of the transformer and bimetal strip combined can be determined. The release current of the combination has the same release time as the secondary current corresponding to this primary current in the operating characteristic of the bimetal strip without the transformer. After verifying that the system is correctly matched, calibration is carried out as described above.

To compensate differences in transformer irons, it is convenient to interpose ahead of the bimetal strip an adjustable series-connected resistance, which can be adjusted so that, for nominal load, the voltage drops will be approximately equal for all current phases. The release times, when saturated instrument transformers are used, are higher than those of a normal bimetal relay.

Practical Design Applications for Hydrostatic Lubrication

By T. L. Corey and E. M. Kipp. (From *Machine Design*, Vol. 27, No. 3, March 1955, pp. 189-196, 13 illustrations.)

This article reviews the basic theory of hydrostatic lubrication and solves, as representative examples, two hypothetical problems illustrating the practical applications of the basic equations.

Recent developments have focused attention on the advantages of hydrostatic lubrication for many important practical engineering applications, inasmuch as hydrostatic bearings have a number of important attributes which can be extremely useful in difficult bearing situations.

Hydrostatic lubrication may be defined in relation to the more widely known and used principle of hydrodynamic lubrication. Hydrodynamic lubrication requires relative motion of bearing surfaces of suitable design for the formation and maintenance of the desired lubricating film; hydrostatic lubrication does not. In hydrostatic lubrication, the film of fluid lubricant between the bearing surfaces is provided by the continuous introduction of fluid under pressure to float the journal on a continuous and moving film of fluid. The manner in which the lubricating fluid is introduced under suitable pressure between the bearing surfaces is critical.

Although both liquids and gases may be used as lubricating fluids in hydrostatic designs, the great majority of theoretical and practical work to-date has been with incompressible fluids such as petroleum and synthetic oils.

Basic Hydrostatic Lubrication Theory

The theoretical basis of hydrostatic lubrication has been covered in detail by Fuller,[1] including examples of practical application. Although the theoretical derivations of the basic relationships presented by Fuller are somewhat complex, the resulting equations are straightforward and are readily applied for preliminary analysis. Briefly, the following major factors are involved in designing suitable bearings in which hydrostatic lubrication is employed :—

(1) Geometry of the bearing surfaces.
(2) Dimensions, shape, and orientation of the high-pressure pad.
(3) Dimensions of the bearing.
(4) Optimum lubricant film thickness.
(5) Effect of bearing temperatures and pressures upon the viscosity of the lubricating fluid.

Bearing-Surface Geometry

In the design of journal bearings, the choice of mating-surface geometry lies between a fitted bearing and a clearance bearing (Fig. 1). Generally speaking, a fitted bearing requires less volume of oil flow and lower operating pressures for a given oil viscosity and load than a clearance bearing operating under the same conditions. The choice will depend upon the conditions imposed on the bearing. High unit loads and low oil viscosities demand greater oil volumes at higher pressures than may be available from a practical, commercially available pump. A clearance bearing accentuates, and a fitted bearing minimizes, these difficulties. Thus, many applications may be successfully designed, using a fitted bearing where a clearance bearing would be impracticable.

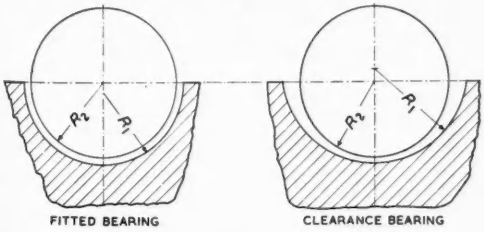

Fig. 1. **Basic types of hydrostatic journal bearings.**

Hydrostatic High-Pressure Pad

The size and shape of the high-pressure pad will be determined by the total bearing area and the load to be lifted. Most frequently, the pad will be rectangular in shape. The optimum area of the proposed high-pressure pad cannot be predetermined by any single rule. In general, it is satisfactory to select a high-pressure pad area of about 2½ to 5% of the normal projected area of the bearing. In any event, this is one of the variables which can be adjusted to some degree in developing a final optimum design. The load-carrying capacity of a hydrostatically lubricated fitted bearing is that of the oil pressure acting on the high-pressure pad area, added to one-half of the oil pressure acting on the remaining surface of the bearing. Evidently, the final choice of pad area and oil pressure will represent the most desirable compromise between these two factors.

The pressure at which the oil is to be delivered to the high-pressure pad is independent of oil-film thickness for a fitted bearing. The situation is somewhat more complicated, however, in a clearance bearing, because the lift capacity of the hydrostatic pad area depends upon a number of additional variables, such as film thickness, size, and orientation of the high-pressure pad with respect to the bearing axis.

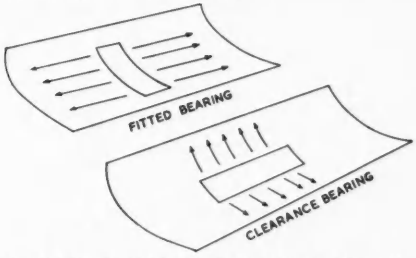

Fig. 2. **Oil flow in fitted and clearance types of hydrostatic bearings.**

For a fitted bearing with a high-pressure pad, maximum oil leakage is along the shaft axis. For this reason, the length of the rectangular slot should be placed normal to the shaft axis (Fig. 2). In contrast, a clearance bearing should have its high-pressure pad placed with the length parallel to the shaft axis, because maximum oil leakage is up and through the side clearance. Thus, if the length of the pad is normal to the direction of maximum oil leakage, greater lifts with less oil flow and more even oil distribution will result.

Bearing Dimensions

Bearing size usually places the second limitation on the size of the high-pressure area which may be used. The remaining bearing-surface unit pressure must be carefully checked, so that permissible unit pressures for the bearing material are not exceeded through removal of bearing area in providing the high-pressure pad.

Optimum Film Thickness

The operating film thickness has the greatest influence on both required oil pressure and flow for

clearance bearings. Extremely low film thicknesses offer the greatest stability and least volume of flow; however, they require greater precision in machining and provide a smaller margin of safety against metal-to-metal contact. On the other hand, precision in mating surfaces may be made less critical by increasing operating film thicknesses at the expense of greater flow requirements and decreased oil-film stability. While there is no substitute for experience in selecting proper operating film thicknesses, the best practice is to select the greatest film thickness consistent with available oil flow without affecting stability to the extent that the film becomes resilient enough to cause the shaft to "dance." In the other direction, film thicknesses as low as 0·0005 in. may be employed without fear of endangering the life of the bearing.

Effect of Bearing Temperatures and Pressures

For a given set of conditions, and beginning with a theoretically suitable bearing design, the success or failure of the bearing in service will depend entirely upon the viscosity of the oil supplied to it. The temperature and pressure at which the bearing is to operate determine actual viscosity of the fluid, and it is this operating viscosity that must be considered. As a qualitative approximation, the temperature rise of an oil within a bearing will be approximately 14° F for every 1000 psi pressure increment. At 5000 psi, the viscosity is approximately double that at atmospheric pressure. The importance of viscosity in hydrostatic applications cannot be overstressed.

Practical Examples

Two hypothetical problems illustrating the practical application of the basic equations are solved as representative examples.

(1) *Fitted Journal Bearing*:—Given conditions are: Bearing load, 100,000 lb; oil viscosity, 100 SSU at 100° F; operating temperature, 150° F; bearing size, 8 in. diameter by 5½ in. long; journal diameter, 8 in.; load area, 120-deg. arc; and journal speed, 150 rpm.

Since this is a fitted bearing, maximum oil leakage will be along the shaft axis. Therefore, the high-pressure slot should be oriented normal to the shaft axis.

The total projected area is 38·5 sq in. Assume a ¾ × 4 in. slot, as shown in Fig. 3. Then, the high-pressure area equals 3 sq in., and the low-pressure area is 35·5 sq in. Thus, operating fluid pressure P for the 100,000-lb bearing load can be determined:—

$$3P + 35{\cdot}5P/2 = 100{,}000$$

$$P = 100{,}000/20{\cdot}8 = 4800 \text{ psi.}$$

In a fitted bearing, maximum oil-film thickness will be at the bottom and will gradually decrease, reaching a minimum at the 120-deg. position. Flow over areas B, C, D, and E only will be considered. Neglecting flow over the corner areas provides a margin of safety in computing flow requirement, in that the effect is that of less restricted flow.

Flow is given by the equation

$$q_l = \frac{Pbh^3}{12\mu l}$$

where b = slot width [in.]; h = film thickness [in.]; l = flow distance [in.]; P = operating pressure [psi]; q_l = flow out of one side [cu in./sec]; and μ = viscosity [reyns (lb-sec/in.²)]. Oil viscosity for this problem equals 100 SSU at 100° F, or 24·6 × 10⁻⁷ reyns.

By substitution, the required flow when h = 0·001 in. can be determined. Thus, axial flow out of both ends of the bearing is 0·550 cu in./sec, and radial flow up around both sides is 0·085 cu in./sec. Total flow is, therefore, 0·635 cu in./sec or 0·165 U.S. gpm.

The actual viscosity of the fluid at the operating pressure of 4800 psi can be estimated from the facts that (1) temperature rise resulting from pressure equals

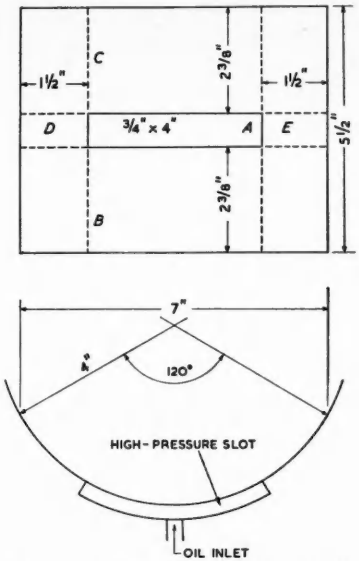

Fig. 3. Dimensions of a fitted hydrostatic bearing, discussed as a practical example.

14° F per 1000 psi pressure increase; and (2) that viscosity increase resulting from pressure is[2]

$$\mu_p = \mu_o e^{BP}$$

where B = constant; P = operating pressure [psi]; μ_o = viscosity at atmospheric pressure and standard temperature [reyns]; and μ_p = viscosity at operating pressure [reyns].

Strictly speaking, B is not a constant, since it varies with pressure and the particular fluid. However, from a practical viewpoint, values for B from Table I are sufficiently accurate for most problems.[2]

Table I. Viscosity Coefficients.

Viscosity [SSU/100° F]	B	Viscosity [SSU/100° F]	B
8950	2·7 × 10⁻⁴	620	2·2 × 10⁻⁴
2460	2·6	310	1·9
1220	1·5	155	1·6

For this particular oil $B = 1{\cdot}6 \times 10^{-4}$, so that the equation for the bearing under consideration simplifies to

$$\mu_p = 2{\cdot}16\,\mu_o$$

Temperature correction is made by reference to a viscosity-temperature plot for the oil used, thus determining viscosity at operating temperature. Total correction for both pressure and temperature can then be expressed as[3]

$$\mu_{pt} = \mu_o e^{BP}\,(\mu_t/\mu_o)$$

or

$$\mu_{pt} = \mu_t e^{BP}$$

where μ_{pt} = viscosity at operating pressure and temperature [reyns]; and μ_t = viscosity at operating temperature [reyns].

Practically speaking, μ_t can be computed by converting viscosity to reyns, using a density of 0·85 to 0·90, since density does not vary appreciably with temperature in practical operating ranges (60 to 150° F).

For the particular bearing, corrections for the effects of pressure and temperature on viscosity do not have an appreciable effect upon flow and pressure requirements, and have not been noted here.

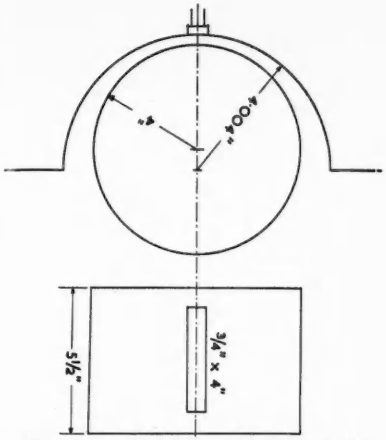

Fig. 4. **Dimensions of a clearance bearing, similar to the fitted bearing in Fig. 3.**

Summarizing, this bearing will require a high-pressure slot with dimensions as shown in Fig. 3, and a positive-displacement pump, capable of delivering about $\frac{3}{16}$ gpm. Since the initial pressure surge will be from 20 to 30% greater than the calculated operating pressure, a pump with a capacity of 6000 psi is indicated. The coefficient of friction can be calculated from Newton's Law of viscous friction

$$F = \mu A \frac{dv}{dh}$$

where A = bearing area [sq in.]; (dv/dh) = velocity gradient [in./sec/in.]; F = shear-resisting force [lb]; and μ = viscosity [reyns].

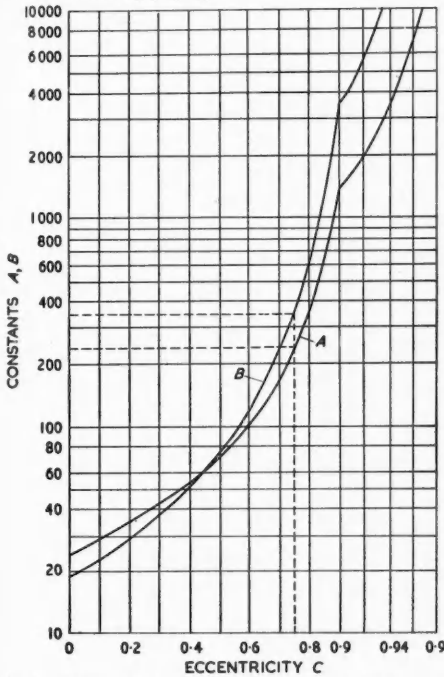

Fig. 5. **Values for constants A and B, used in clearance-bearing calculations to incorporate eccentricity effects.**

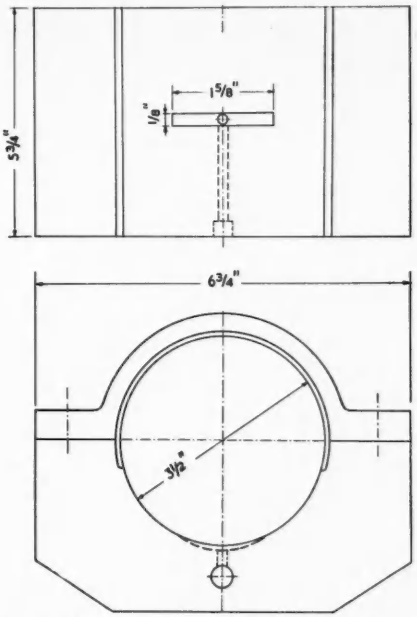

Fig. 6. **Example of a bearing using air as the hydrostatic fluid, and intended for operation at an ambient temperature of about 1200° F.**

For 150 rpm, velocity is 62·83 in./sec, and

$$F = (24{\cdot}6 \times 10^{-7})\,(35{\cdot}5)\,\frac{62{\cdot}83}{0{\cdot}001} = 5{\cdot}49$$

For this value of F, the coefficient of friction f is

$$f = 5{\cdot}49/100{,}000 = 0{\cdot}0000549$$

(2) *Clearance Bearing*:—For direct comparison with the fitted bearing, the same given conditions will be assumed. The only difference is that the bearing diameter is 8·008 in.

Oil leakage in a clearance bearing will tend to flow up around the sides. Therefore, the slot should be placed parallel to the shaft axis (Fig. 4). The desired operating film thickness h will be assumed to be 0·001 in. Then, eccentricity C is

$$C = 1 - \frac{h}{mr} = 1 - \frac{0{\cdot}001}{0{\cdot}001 \times 4} = 0{\cdot}75$$

where h = operating film thickness [in.]; m = clearance modulus [in./in.]; and r = journal radius.

Equations used to calculate the required oil flow to provide hydrostatic lubrication and the pressure at which the oil must be supplied involve two constants, A and B. Values for these constants are functions of the eccentricity, as shown in Fig. 5,[4] and will be found to be: $A = 237$ and $B = 343$. The required flow with no correction for temperature and pressure is

$$q_l = \frac{Wm^3 r}{\mu A}$$

where q_l = flow up one side [cu in./sec] and W = load [lb].

Flow up one side is, by substitution, 0·685 cu in./sec. Axial flow out of the ends of the bearings is disregarded; total flow is thus 1·37 cu in./sec or 0·356 gpm.

The operating pressure at this flow is given by

$$P = \frac{\mu q_l B}{bm^3 r^2}$$

with symbols as previously defined. Bearing operating pressure is thus 9050 psi.

Correction of the oil viscosity for the operating temperature and pressure will change the viscosity to about $16{\cdot}8 \times 10^{-6}$ reyns, and the corrected design flow to 0·52 gpm. Thus, this bearing would require a high-pressure slot with dimensions as shown, and would require a positive-displacement pump capable of delivering $\frac{1}{2}$ gpm at the indicated operating pressure, with the desirable added margin of 20 to 30% reserve.

Compressible Fluids

This article has dealt entirely with hydrostatic lubrication involving the use of incompressible fluids. The theoretical development of practical equations for compressible fluids has not progressed to the same degree as in hydrostatic lubrication using incompressible fluids. However, the use of air as a lubricant, for example, is not new,[5-8] and air has been widely applied in the lubrication of lightly loaded, high-speed spindle bearings. It has also been used for special applications, such as extremely high-speed centrifuges. The load-bearing capacity of air at moderate pressure is rather surprising, as indicated by Table II for spheres of the indicated diameters.[8]

Fig. 6 is an example of a bearing intended for operation at an ambient temperature of approximately 1200° F, and involving the use of air as the hydrostatic fluid. The bearing is of the partial-journal sleeve type, with a maximum design load of 200 lb and an operating speed of 65 rpm. Requirements for this bearing are satisfactorily met with the use of air pumped into the hydrostatic pad area at a pressure of 35 psi and a computed volume of 1·9 cfm. Actual consumption of air will be considerably less than the calculated volume, since the latter was computed for room temperature. In this case, the ratio of the high-pressure pad area to the total projected bearing area is 1·8%, the latter area being 18·7 sq in.

Table II. Load-Carrying Capacity of Spherical Air-Film Bearings.

Sphere diameter [in.]	Line air pressure [psi]	Seat air pressure [psi]	Film thickness [in.]	Load [lb]	Flow [cfm]
2	80	70	0·005	140	1·23
4	80	70	0·004	560	1·26
6	80	70	0·003	1260	1·19

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U.S.A.

Stress Corrosion of Stainless Steels

By J. J. Heger. (From *Metal Progress*, Vol. 67, No. 3, March 1955, pp. 109-116, 11 illustrations.)

Of the four types of corrosion encountered with stainless steels, i.e., general corrosion, intergranular corrosion, pitting corrosion, and stress corrosion, the latter is, by comparison with the other types, a relatively new subject. Its newness, however, may be attributed, not to the absence of stress corrosion in the early uses of stainless steel, but rather to the fact that many early investigators did not recognize it.

Like pitting corrosion, stress corrosion is caused by a localized breakdown of the protective film, corrosive attack being accelerated by stresses, and cracking results. Since 1939, several service failures from stress corrosion have been reported, the corroding environments including sulphite liquor, ethyl chloride, steam at 950° F, mains water, humid air at 185° F, brine, crude petroleum, marine atmosphere, orange juice, dye liquor, inhibited calcium chloride, sulphurous and sulphuric acids, and boiling sodium hydroxide.

Although the reason is not completely understood, stress corrosion in stainless steels appears to be confined largely to the austenitic alloys. Indeed, few service failures of the ferritic alloys have been reported in the literature, and Scheil[1] states that they are practically immune. On the other hand, Ffield[2] tested various modifications of the 12 to 16% Cr steels and found that, without exception, these steels could be made to stress-crack. Later, Uhlig[3] described failure by cracking of the ferritic steels as probably caused by hydrogen embrittlement. Perhaps one reason for the lack of reported service failures of the ferritic alloys is that they were explained by other mechanisms, such as fatigue or quench cracking.

One group of service failures has been investigated in the laboratories of the U.S. Steel Corporation over a six-year period. Because of the widespread belief that chlorides or halides must be present before stress-corrosion cracking will occur in stainless steels, the environments in which they occurred are classified as (*a*) environments definitely containing chlorides or halides; (*b*) environments in which the presence of chlorides or halides was suspected; and (*c*) environments containing no chlorides or halides.

(*a*) *Environments containing chlorides* :—

Failure occurred in a jacketed milk-pasteurizing tank, with an inner shell constructed of cold-formed and welded 18-8 stainless steel and an outer shell of carbon

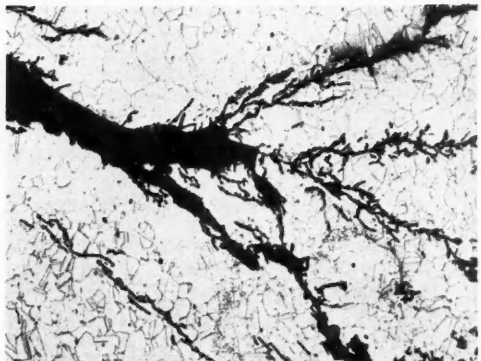

Fig. 1. **Brine side of jacketed milk tank, showing trans-granular stress-corrosion cracking through areas containing intergranular carbides. Etchant, sodium cyanide.** (×75)

steel. One surface of the 18-8 steel was exposed to milk and the other to brine. After 10 years' service, the stainless steel failed by cracking. No corrosion had occurred on the milk side of the steel, but pitting occurred on the brine side. The cracking, which was well removed from the heat-affected zone of the weld, was transgranular, typical of a stress-corrosion failure.

Another jacketed milk tank of welded construction failed in a similar manner, with the additional interesting feature shown in Fig. 1 that, although there was evidence of intergranular carbide precipitation, the cracking that occurred was transgranular.

Another example was a steam-jacketed evaporation dish constructed of cold-formed and welded 18-8 Mo, used to evaporate a slightly alkaline solution of calcium chloride from a concentration of 25% to 50%. During evaporation, the temperature increased from 122 to 302° F. Cracking occurred near the weld 60 days after installation of the dishes (Fig. 2). Examination revealed that pitting had occurred, the cracking was transgranular, and the grains exhibited strain lines. Probably the strain lines resulted from residual stresses originating during fabrication, although the thermal cycle employed during operation may have exaggerated their effect.

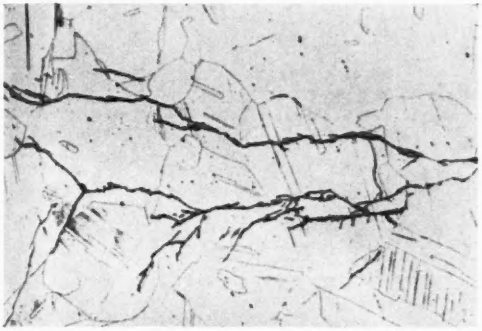

Fig. 2. **Transgranular cracks and strain lines in 18-8 Mo evaporation dish used with calcium chloride solution. Etchant, oxalic acid. (×50)**

The inner liner of a cold-formed and welded 18-8 coffee urn, exposed to mains water at temperatures not exceeding 212° F, failed by transgranular cracking, even in those locations which showed intergranular carbide precipitation at a higher magnification.

(*b*) *Environments in which chlorides were suspected :—*

In the next five failures to be considered the exact natures of the environments were not known, but they were suspected to contain chlorides or halides.

In this category, an 18-8 welded tank cracked, and the cracking propagated from the weld metal into the parent metal. Although intergranular carbide precipitation had occurred, the cracking was transgranular. A surface leach of this sample disclosed the presence of chlorides.

In the case of a horizontal milk-storage tank fabricated of ¼-in. 18-8 stainless steel, stress-corrosion cracking occurred in a weld which had been repaired and in the parent metal near the weld deposit. Where carbide precipitation had occurred, the cracking was intergranular ; where there was no carbide precipitation, cracking was transgranular.

Pitting and cracking occurred near a threaded ferrule welded to a cold-bent 18-8 stainless-steel tube used for conveying orange juice. Cracking originated on the inside of the tube and was transgranular.

Textile dyes were the environment responsible for the next failure—in a drum of cold-formed and welded 18-8 stainless steel, serving as a reel over which fabric moved, and exposed to dye vapours as well as to solution. The composition of the solution was not known,

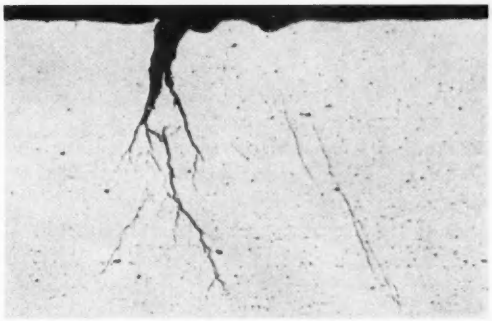

Fig. 3. **Transgranular cracks in stainless-steel expansion joint, apparently propagating from a pit on the inside surface.**

except that it contained a little sulphuric acid. The cracking was transgranular and was located outside the weld areas. This failure occurred after one year of service.

Stress-corrosion cracking occurred, after three months' service, in a cold-formed and spot-welded 18-8 compressor rotor. The cracks were transgranular and transverse to the residual tensile stress caused by the spot welds.

(*c*) *Environments containing no chlorides :—*

One failure in an environment believed to have contained no chlorides occurred in a cold-formed 18-8 Cb bellows-type expansion joint. Composition of the gas carried through the inner sleeve of this joint was 0·1% carbon monoxide, 0·7% hydrocarbons, 0·4% carbon dioxide, 0·3% oxygen, 5 to 6% hydrogen, and balance nitrogen. The gas was under 100 psi pressure and at a maximum temperature of 400° F. Transgranular failure through a ⅜-in. wall occurred in less than 60 days. Pitting was observed on the inside of the joint near the cracks. Pitting and perforation, but no cracking, occurred in the sleeve. Probably, gas leaked in between the sleeve and the joint and some of the impurities in the gas condensed. The condensate evidently contained either H_2SO_4 or H_2SO_3, because a residue scraped from the joint contained sulphur. Neither chlorides nor halides were found. As shown in Fig. 3, the cracking was transgranular, and at least some grew from a pit.

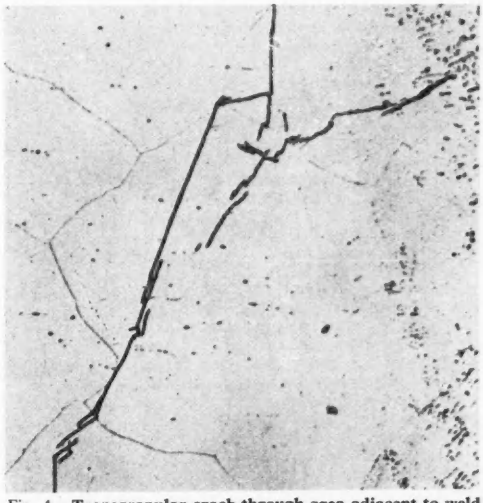

Fig. 4. **Transgranular crack through area adjacent to weld in a kettle. Etchant, sodium cyanide. (× 100)**

A welded kettle of $\frac{5}{8}$-in. stainless steel, type 309 (25-12), which was used to hold molten sodium hydroxide at 700° F, failed by cracking near the welds and around stress raisers. The cracks were transgranular, even in those areas containing intergranular carbide precipitation (Fig. 4). No other attack, such as pitting, was observed.

Laboratory Investigations

Laboratory investigations on the stress corrosion of stainless steel have been directed at studying the environments involved and the stresses needed to cause cracking. Environments which caused cracking in laboratory tests are ammonium chloride; calcium chloride; cobalt chloride; lithium chloride; magnesium chloride; mercuric chloride; sodium chloride; zinc chloride; and moist hydrogen sulphide.

With one exception, all of the solutions were chlorides and the belief therefore arose that chloride-containing environments were the only culprits. The cracking in moist hydrogen sulphide reported by Rees[4] in cold-drawn 18-8 and hardened 12% Cr steel wire certainly refutes this idea.

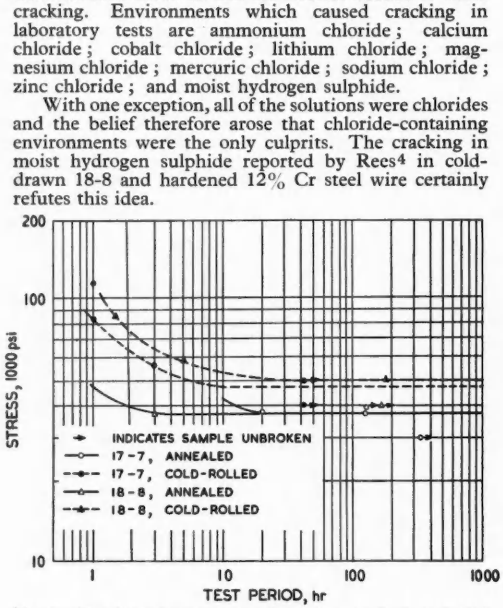

Fig. 5. **Results of stress-corrosion tests on 17-7 and 18-8 stainless steels in boiling 24% $MgCl_2$ solution.**

All investigators agree that tensile stresses are necessary to cause cracking. Franks, Binder, and Brown[5] report a "limiting" or "threshold" stress, which must be exceeded before cracking may occur, as shown in Fig. 5, which gives the results of stress-corrosion tests on 17-7 and 18-8 stainless steels in boiling 24% $MgCl_2$ solution. The yield strength of the 17-7 steel was 28,000 psi annealed and 157,000 psi cold-rolled; the corresponding figures for the 18-8 steel were 26,000 and 125,000 psi respectively. It will be noted that the stress-time curve for stress-corrosion cracking resembles the *S-N* curve for fatigue, and that the "limiting" or "threshold" stress varies with the prior treatment of the metal. Undoubtedly, this stress also varies with environment.

Prevention of Stress Corrosion

Inasmuch as stress corrosion is caused by the simultaneous action of both stress and corrosion, a reduction in the intensity of either factor should reduce, if not entirely prevent, such failures. In addition, selection of the proper alloy for the environment may minimize stress-corrosion cracking.

Stresses originating during service may be modified by changes in the design and operation of equipment. For example, the causes of mechanical vibration might be eliminated or modified, or suitable expansion joints used to minimize the effects of thermal fluctuation.

Residual stresses seem to cause a majority of the stress-corrosion failures. They result from cold forming and welding during fabrication, and may be removed by stress-relieving heat treatments. Certainly, stress-relieving after cold forming and welding is desirable.

Inasmuch as the loads causing the damage induce tensile stresses, Krivobok[6] has suggested that the surfaces of the metal be compressed by shot-peening. Certainly, this is a worthwhile suggestion.

The effect of the corroding environment may be modified by the use of inhibitors or by cathodic protection. Inhibitors such as chromates and phosphates minimize the localized type of attack. For example, in the pasteurizing tank already mentioned, a chromate inhibitor was used; although stress corrosion did occur, the service life of the metal was ten years. Without an inhibitor failure might have occurred much earlier.

Cathodic protection of stainless steel against stress corrosion was suggested by Mears, Brown, and Dix,[7] who list the metals which, when connected electrically with stainless steel, prevent it from cracking in a sodium chloride solution. Many of the jacketed vessels described are examples of stainless steel connected to carbon steel, and in all these vessels cracking did not occur before seven to ten years of service. Perhaps the reason why cracking occurred at all was that corrosion products accumulated on the carbon steel, thus lowering the difference in electrical potential between the two steels, thereby decreasing the intensity of cathodic protection.

Since stress corrosion results in a localized breakdown of the protective film, selection of the proper stainless alloy to resist localized breakdown may be one remedy. For example, many corroding environments which attack 18-8 stainless steel do not attack 18-8 with suitable additions of molybdenum. In such environments, use of 18-8 Mo may minimize the danger of cracking.

Since the intergranular type of stress-corrosion cracking is associated with the intergranular precipitation of chromium carbides, additions of columbium or titanium in amounts sufficient to stabilize the carbon or the use of the low-carbon (0·03% C max.) stainless steels should prevent this type of cracking.

Conclusions

The service experiences and laboratory investigations just described permit some generalization about the conditions under which stress-corrosion cracking will occur in stainless steel.

Obviously, the metal has to be simultaneously subjected to stresses and exposed to a corroding environment. Tensile stresses are needed, and these may be either applied or residual. Residual stresses appear to have caused most of the stress-corrosion failures encountered during service. Indeed, in practically every failure discussed, the stainless steel was in the cold-formed and welded condition, and thus subjected to severe residual stresses. Therefore, the observation made by Dix[8] that no stress-corrosion cracking in aluminium alloys is caused by operational stresses alone

(*Concluded on page* 302)

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British Industrial Developments

800-Ton Hydraulic Plate-Stretching Machine

Stretching machines include essentially a pair of grips, designed to hold the sheet uniformly and firmly along the entire length of two opposite edges and to apply to it, by controlled hydraulic pressure, tensile strain of the required magnitude. The latest machine, of 800 tons capacity, manufactured by Joshua Bigwood & Son Limited, of Wolverhampton, embodies an improved and patented type of grip head, modern hydraulic equipment, a pre-flattening device to ensure easy entry of buckled plate into the grips, and centralized control.

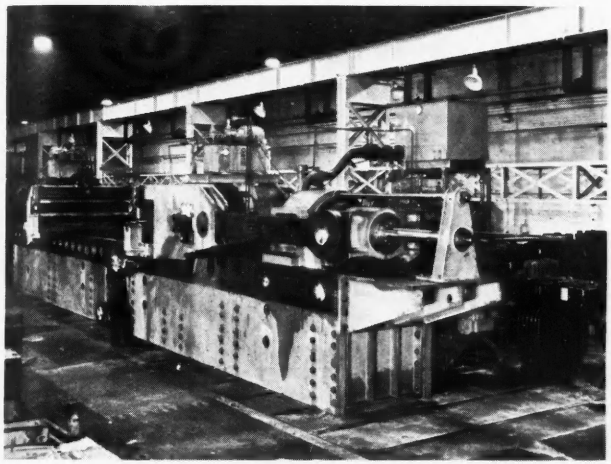


Fig. 1.

The main frame of the new machine, the general arrangement of which is shown in Fig. 1, is fabricated from solid steel plate, the two side frames being divided into sections for ease of construction, transport, and handling; these frames are bolted together at the flanges and, when erected, are secured by heavy link plates on the tension side of the neutral axis. The frame rests on roller supports which permit it to deflect without restraint under load. A series of large-diameter holes is bored at intervals of 18 in. in the upper part of the side frames. These are lined with hard chromium-plated steel bushes and provide for the location of the locking bolts which transfer the load from the movable grip head to the main frame members. These bushes are replaceable in the event of wear or damage to the holes. Mounted on the bed below the level of the locating holes and on top of the bridge pieces are two joists, rigidly fixed to the frame and each carrying on its upper flange a flat-bottomed rail, forming a runway for the movable grip head. Housed also between the frames are the traversing drives for the movable grip head, the limit switches for grip-head alignment with locating holes, and the power-supply cables and reels.

The main cylinder is machined from a special steel hollow forging carried in a massive steel yoke, anchored to the frames by heavy pins. The main ram is bored to take the supplementary piston which brings the grip head to the initial position and provides take-up at high speed. A steel crosshead, supported on rollers, takes the overhung weight of the ram and links, and relieves the packings of vertical loads. The crosshead is coupled to the grip head by two heavy steel draw links, secured at each end by large-diameter trunnion pins. The cylinder is fitted with a high-capacity relief valve to return the oil to the tank directly, in the event of rupture of the sheet. All pressure packings throughout the machine are of the chevron type.

The grip heads are each fitted with a patented sectional grip assembly, wherein the top and bottom grip blades of special-quality steel are carried in segmental blocks riding on hardened and ground steel rollers, which bear on hardened and ground inclined faces. This construction provides for handling by one set of grips an exceptionally wide thickness range ($\frac{3}{16}$ to $1\frac{3}{8}$ in.). The grip assemblies are actuated by hydraulic cylinders, one on each grip head, which operate through an equalizing link system. Mounted on each grip head is a self-contained motor-driven subsidiary hydraulic pumping unit, the electric cable being wound on a spring-loaded reel.

Movement is imparted to the travelling grip head by heavy-link draw chains driven by sprockets from an electric motor and reduction gear housed between the frames. A special feature is the support of the weight of this grip hea- (21 tons) on a heavy disc-spring mountd ing, so that, during adjustment, it is supported on its rollers clear of the bed and very little tractive effort is required to effect movement. When the stretching load is applied, there is a component of force which pulls it down onto the bed, so that the load is supported on a large area. Tension adjustment is provided for the chains through adjustable jockey rollers. The drive is taken from the motor, which is push-button controlled from a central control desk through an electromagnetic clutch and sprocket drive to the final reduction kearbox which drives both the draw chains. The two anchor pins which lock the moving grip head are moved outwards by hydraulic cylinders to engage the holes in the frames when the grip head has been traversed to the required position. The pins, having passed through the holes in the frame, enter holes in the outer arms of the grip-head casting and thus, under load, are in double shear and sustain a minimum bending moment. These anchor pins are retracted hydraulically when it is desired to change the position of the grip head.

Hydraulic pressure to the main and supplementary rams is supplied by a double pump unit, driven by an 80-hp motor. This unit consists of two identical pumps; each has five plungers and a capacity sufficient for half-speed ram operation. A by-pass valve enables either or both units to be used. Stepless speed control is obtained by means of metering and by-pass valves. The maximum working pressure is 5000 psi. The grip-head subsidiary pump units are driven by a $7\frac{1}{2}$-hp motor and operate at a maximum pressure of 4000 psi.

The machine, which is believed to be the largest of its kind in Europe, is controlled completely from a separate control desk (Fig. 2), which may be sited in any convenient position and raised to give full view of all working members of the machine. Control is by electric push-button switches, operating the solenoid valves of the hydraulic systems. The main ram is controlled by three push-buttons, giving "Load,"

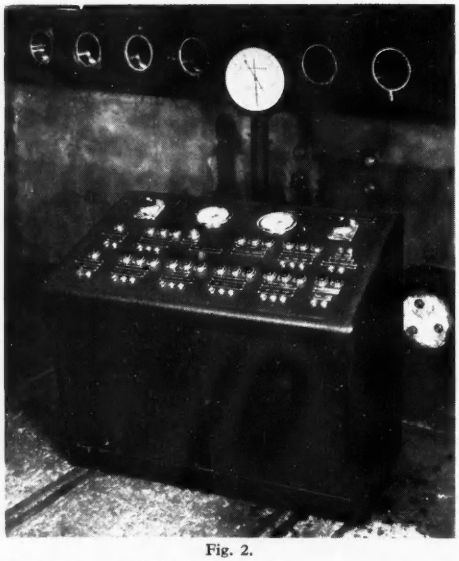


Fig. 2.

" Unload " and " Hold-pressure " operating conditions. The supplementary-cylinder valve-gear controls for each set of grips, the locking pins, and the adjusting motor controls are also incorporated in the control panel. The setting of all controls is shown by indicator lamps. An electrically coupled pair of magslips provides an indication of the position of the travelling head, whilst a second pair indicates on a calibrated dial the movement of the ram-operated grip head under load, and thus shows the amount of elongation or extension to which the sheet has been subjected. The controls are provided with interlocks, so that the moving head grips can be operated only when the locking pins are in engagement, while the locking pins cannot be operated unless the grip head has been correctly positioned.

Fluorescent Lighting Fitting

A new fluorescent lighting fitting, claimed to have a number of unique features, has been introduced by Metalform Ltd., of London, W.C.1. Intended primarily for industrial and commercial use, the fitting is adjustable to give a wide choice of mounting positions and incorporates movable reflectors which can be locked to provide various cut-off values. The fitting is also designed to provide a high proportion of light radiation above the horizontal, to ensure adequate ceiling and surround illumination.

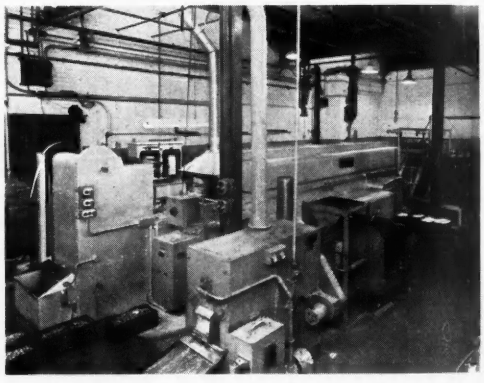
The mounting plate can be fixed directly to walls or ceiling, to a standard conduit box ; alternatively, it can be clamped directly to conduit for bench or other locations. For pendant mounting the plate can be attached to two tubular down-rods or suspension chains. To simplify installation the mounting plate is a separate unit—after being fixed in position, the control-gear box, which supports the assembly, is slid on and is held firm by fixing screws. The front plate of the box can be removed for connecting up, and to give direct access to the control gear.

The tubular drawn rod supporting the lamp and reflector assembly can be adjusted to alter the mounting angle, and the angular separation of the reflectors is also adjustable to give a range of cut-off angles. The reflectors are detachable and can be used either singly or together, or they can be reversed to form an indirect lighting fitting. The reflectors and control-gear box are fabricated from sheet metal, stove-enamelled in a range of colours. The insides of the reflectors are white.

Continuous Heat-Treatment Installation

An example of the modern trend in heat-treatment equipment is the continuous, electrically heated furnace supplied by G.W.B. Furnaces Limited, of Dudley, to the Ormond Engineering Co., Ltd., of London. This company manufactures top-quality high-tensile bolts, and the furnace supplied carries out continuous hardening and stress-relieving of these items. The unit has a maximum electrical rating of 105 kW arranged in two heating zones, each controlled independently. The first zone is governed by a Foster indicating controller, while the second zone is controlled by a two-point recording controller, which also gives a permanent positive record of temperature conditions at two points along the heating chamber.

The whole installation is automatic in operation, the only attention needed being periodic charging of the loading hopper and removal of the heat-treated charge from the discharge end of the continuous-quench extractor. The furnace is designed for a nominal maximum output of 5 cwt of hardened bolts per hour, although in other similar installations a higher output of up to 6 cwt per hour has been obtained on normal production runs. The charge falls by gravity from the hopper onto an automatic electro-mechanical vibratory feeder, which ensures even distribution of the articles over the full width of the mesh belt conveyor. The belt is 18 in. wide and is fabricated of heat-resisting steel wire of suitable weave and analysis to withstand the high temperatures encountered. The furnace is capable of a maximum operating temperature of 900° C.



After passing through the heating chamber, 14 ft 6 in. in length, the charge drops through a chute situated in the hearth at the rear end of the furnace, and falls into the oil-quench tank. A continuous woven-wire quench-extraction conveyor removes the bolts from the oil and they then fall into pans for final removal. The furnace conveyor and quench-conveyor drives are independent, so that a high degree of flexibility in operation may be obtained. The quenching oil is continuously cooled by means of a Heenan and Froude air-cooled oil cooler, capable of cooling 1770 gallons of light quenching oil per hour from 113° F down to 95° F, with air entering the cooler fans at 60° F.

In order to cut down oxidization or scaling of the charge, a protective atmosphere is introduced into the furnace heating chamber. This atmosphere is derived from a standard G.W.B. exothermic plant, in which a controlled ratio of town gas and air is burnt inside a refractory-lined combustion chamber. These atmosphere plants are very compact in design, as can be seen from the accompanying photograph, in which the plant is on the right-hand side in the background. The charge hopper, of 5 cwt capacity, can be seen on the left, and the degreasing unit in the middle foreground.

Electronic Air Filter

Electronic air cleaning provides an extremely high degree of air cleanliness and has a very wide field of applications. The "Electro-Klean," announced by Air Control Installations Ltd., of Ruislip, Middlesex, is a dry-type electronic filter (Fig. 1) designed especially for small air-conditioning units, and is based on the application of an electrostatic charge to a unit-type filter cell containing a pleated mineral-fibre medium. It brings all the benefits of electronic air cleaning—already available for larger installations through the company's "Electro-PL" filter—within the range of smaller applications.

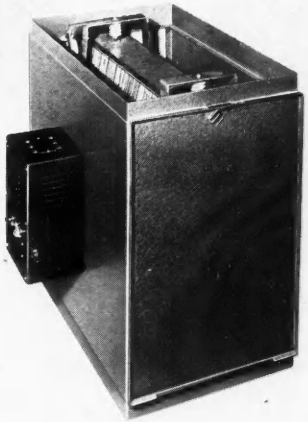


Fig. 1.

The "Electro-Klean" unit comprises a mild-steel frame containing one or more filter cells, as shown in Fig. 2. These cells are supported in the frame between two metal grids, one charged and the other earthed, producing a powerful electrostatic field in the filter media to attract and hold dust and smoke particles. Each filter cell consists of a mineral-fibre filter medium. The latter is composed of very fine filaments, compressed into a thin porous sheet, bonded together at each point of contact with a thermoplastic under heat and pressure, and finally accordion-pleated. The edges of the pleated medium are coated with a metallic compound which contacts the grids and serves as a conductor for the electrical potential, to ensure uniform distribution of the electrostatic charge over the entire filter cell. When the filter cells acquire their full dust load they are easily removed and replaced by clean cells. Each filter cell comprises an area of more than 28 sq ft of filtering media.

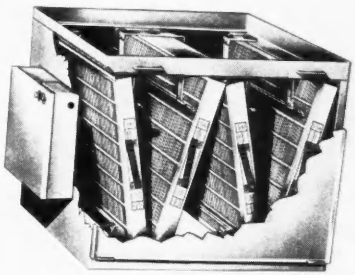


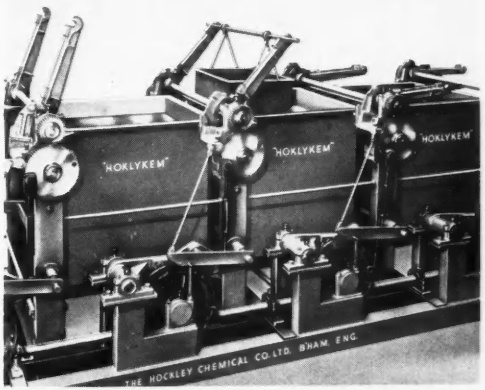
Fig. 2.

The entire casing and exposed parts are earthed. Should the side panel giving access to the filter cells be inadvertently removed without turning off the power pack, a safety device automatically earths all charged parts. Furthermore, the front cover of the power pack is so arranged that it cannot be removed without first removing the power input plug. Finally, the high voltage is non-lethal, owing to the special design of the power pack. This power pack is a compact, self-contained unit, which supplies and maintains the electrostatic charge within the filter cells, and is designed to give an output of 500 μA at between 11·5 and 12·5 kV. The output is derived from a radio-frequency oscillator which operates at a frequency of between 80 and 100 kc/s. R.F. radiation is negligible.

The filter is stated to be many times more efficient than throw-away filters in removing fine dust and smoke particles, and also to be more efficient than ordinary filters in the removal of airborne bacteria, mould spores, and pollen. Furthermore, the device requires no water or drain connections, is ready for immediate operation, and requires no washing or re-oiling. In addition, operation is completely silent, power consumption is virtually negligible, and all parts are accessible.

Automatic Cam-Operated Transfer Plant

The automatic cam-operated transfer plant, for phosphating, pickling, cleaning, etc., manufactured by The Hockley Chemical Co. Ltd., of Birmingham, is fundamentally a swing-over arm arrangement for transferring baskets of work from one tank to another. A pair of arms is provided for each tank and each pair is individually cam-operated, which means in effect that each motion can be timed separately, i.e., from a dip to the full-time cycle of the machine. Furthermore, the cam can be designed to dwell before transfer for draining, or to dwell in any desired position for spraying, etc. The machine is produced in units of two and three tanks, and a plant of any desired length can be built up, the units being bolted together and the driving shaft joined up by a coupling.



Barrels can be provided on this machine for cleaning and phosphating lines, these being positioned on the arms, with the shaft of the barrel in place of the usual work rod. In this case, a driving helical gear is located at the extreme end of this barrel shaft and, disposed longitudinally down the side of the machine, opposite to the mechanism, is a drive shaft driven by a separate motor with helical gears at appropriate intervals, to mate up with the barrel gear when transferred; the barrel after being transferred rests and runs in bronze "V" blocks. Additional refinements include the provision of two- or four-speed motors; alternatively,

a variable-speed drive for controlling barrel speeds can be supplied.

A horizontal conveyor system for inclusion in this plant has also been developed. This consists of two horizontal chains mounted at the sides of the process tanks, these chains being fitted with attachments which carry the work rod along skid rails through the bath, where they are automatically picked up and transferred to the next tank by means of the swing-over arm. The conveyor is arranged for driving from the existing mechanism and timed to receive and eject the work rods at the appropriate cycle time.

Provision can also be made on all these machines for tipping the baskets or jigs at the last station, and returning the empty baskets to the loading end by means of a mechanism in the form of a light chain conveyor, running over the top of the machine and depositing the empty basket back at the loading point. The power consumption of these machines is virtually negligible, a $\frac{3}{4}$-hp motor being quite adequate for driving a 3-tank unit (4 sets of arms) with a work load per basket of approximately 50 lb.

Deep-Hole Drilling Machines with Power Indexing Fixtures

For some time, deep-hole drilling machines for a variety of mass-production uses have been produced by Adcock & Shipley Ltd., of Leicester, these machines being usually of the horizontally opposed type, using multi-spindle heads to machine a number of components at one loading. In certain cases, this firm is offering hydraulic indexing fixtures, with a view to increasing the productive capacity of these machines still further. These have been designed to enable loading to be carried out at one station whilst drilling is taking place at another.

Fig. 1 is an illustration of a machine of this type, designed to drill the oil holes in 4-cylinder crankshafts for Humber Ltd., of Coventry. In Fig. 2, the two-station indexing fixture can be seen, with a crankshaft loaded with No. 1 throw in the upper position in the loading station, and a crankshaft with No. 4 throw in the upper position in the drilling station.

The method of operation on this machine is to load the crankshaft with No. 1 throw uppermost and to drill holes from the main bearings to No. 3 and No. 4 big-end bearings. The crankshaft is then reloaded with No. 4 throw uppermost, and holes are drilled from the main bearings to No. 1 and No. 2 big-end bearings.

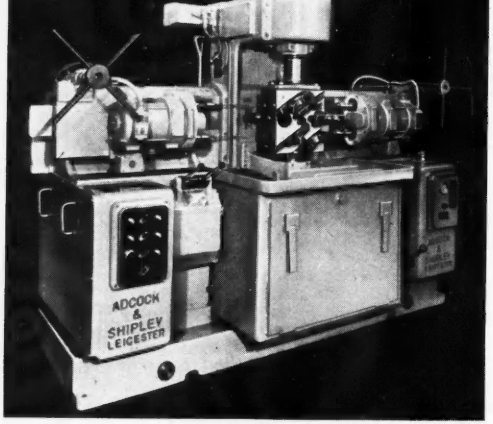


Fig. 1.

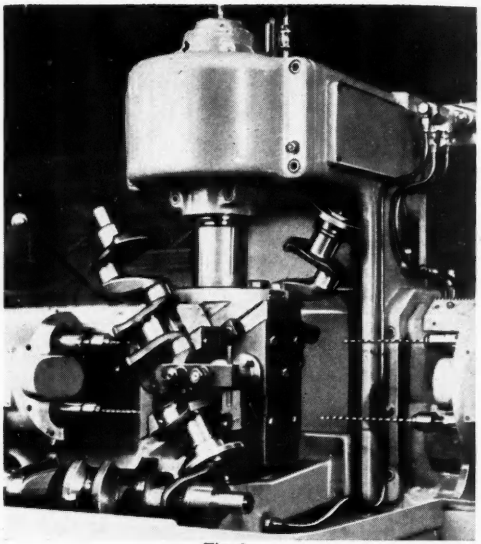


Fig. 2.

It should be understood that the total production time for these crankshafts is the time for two drilling operations plus two indexing operations. Since the holes are drilled from both ends, not only is the length of hole to be drilled by each individual drill shortened, with beneficial effects to the drill life, but also drilling time is reduced by 50%.

These deep-hole drilling machines are fed hydraulically by a servo-mechanism operated from cams rotated by a separate feed motor, the drive of which is equipped with pick-off gears to enable cycle times to be changed. The two-spindle drill heads are horizontally opposed and mounted on slides over the cabinet base, enabling the component to be simultaneously drilled from both sides. The drills are of $\frac{7}{32}$ in. diameter and are fitted to standard collets, each having individual adjustments of 1 in. The drill heads themselves, by means of capstan-type wheels, have a hand adjustment of $1\frac{3}{4}$ in. The heads have a fast traverse rate of 300 in. per min, changing down to a drill feed rate of 0·0019 in. per spindle revolution at 1020 rpm. These feeds and speeds can be changed by means of the pick-off gears.

The machine consists of a base acting as the coolant reservoir, upon which is mounted a box section containing the hydraulic control mechanism. On the extreme left and right are two cabinets extending forward. The left-hand cabinet, fronted by a switch panel, contains the electrical control gear, while the right-hand cabinet contains the hydraulic power unit and is fronted by its instrument panel. Coolant is fed from a large-capacity centrifugal pump mounted in the base to guide-bushes in the fixture, thus ensuring powerful jets down the holes, clearing of swarf, and cooling of the work and drills. Lubrication is by a one-shot system to the drill-head slides and is operated by a foot-pump near floor level at the front of the machine. Special attention has been given to the problem of swarf accumulation, the front of the machine being equipped with a large sheet-metal cabinet, enabling the coolant and swarf to be collected in a specially designed sheet-metal swarf barrow housed inside this cabinet. The bottom of the swarf barrow is fitted with grids to permit coolant to drain out, while the front of the cabinet is hinged at the bottom to allow the swarf barrow to be pulled out on its wheels, thus enabling it to be easily removed by a fork-lift truck and to be replaced with a similar empty swarf barrow.

CLASSIFIED ABSTRACTS

Numerous important abstracts which, for lack of space, cannot be published in our main editorial columns are regularly included in condensed form in this section. Subscribers may obtain photostat copies of all original articles at cost.

AERONAUTICAL ENGINEERING

Recent Developments in Aircraft Control.

By R. C. SEAMANS, F. A. BARNES, T. B. GARBER, and V. W. HOWARD. (From *Journal of the Aeronautical Sciences, U.S.A.*, Vol. 22, No. 3, March 1955, pp. 145-164, 13 illustrations.)

PILOTED aircraft can be controlled directly by the pilot or indirectly through the use of instruments, electronics, and servo-equipment. Pilotless aircraft can be controlled by means of programmers, radio links, or homing systems. However, the present trend toward supersonic speeds is introducing more violent changes in the aerodynamic loading of aircraft, especially in manœuvring flight. As a result, large hinge-moment variations are expected. In addition, the centre of pressure shifts position with Mach Number, causing significant changes in static stability. Consequently, equipment to position the control surfaces and to stabilize the aircraft in the manœuvre desired by the human operator appears desirable in both inhabited and uninhabited aircraft.

In this paper, the mechanization of a pitch control system is discussed and its design is analysed in non-dimensional form. In the analysis, consideration is given to changes in static stability, to the effect of fuselage bending, and to the location of gyro elements in the aircraft. In addition, the ability of the control system to minimize the effect of gust interference is discussed.

Based on the material presented in this paper and their personal experience, the authors draw, among others, the following conclusions :—

(1) An integrating gyro unit is ideally suited for use in a pitch-rate control system.
(2) The pitch-angle feedback sensitivity of the pitch-control system has both an upper and a lower limit when the aircraft is statically unstable.
(3) The long-period motion of the aircraft has a noticeable effect on the response of the pitch-rate control system, but does not influence the system stability.
(4) The pitch-angle deviation of the aircraft, resulting from vertical gust velocities, can be reduced appreciably by the tight-loop stabilization of the pitch-rate control system.
(5) The pitch-angle response at the antinode is not affected by first-body bending when the undamped natural frequency of bending is large in comparison with the short-period natural frequency of the aircraft.

CORROSION

Geometric Factors in Electrical Measurements Relating to Corrosion and Its Prevention.

By W. J. SCHWERDTFEGER and I. A. DENISON. (From *Journal of Research of the National Bureau of Standards, U.S.A.*, Vol. 54, No. 2, February 1955, pp. 61-71, 15 illustrations.)

BECAUSE of the electrochemical nature of corrosion in aqueous media, the study of current and potential relations pertaining to galvanic couples has provided much useful information concerning the mechanism of corrosion and its prevention. However, relatively little attention has been given to the spacial relations between the anodic and cathodic areas comprising the galvanic couples. In a given medium, potentials are affected by the polarization of the elements of the couple and also by the conductivity of the electrolyte. In order to study the potential pattern around a galvanic couple most effectively, measurements might be made with the couple in a solution which causes relatively little polarization. The conclusions reached from these measurements, insofar as geometrical considerations are concerned, should also be applicable to all galvanic couples of similar configuration, regardless of polarization or electrolyte conductivity. It might even be true that, in certain environments, such geometrical considerations become relatively insignificant, for example, in a highly conductive electrolyte producing considerable polarization.

The plan of the investigation described in this paper was to make an experimental study, based on theory, of the potential distribution in the vicinity of line electrodes immersed in a conducting medium and to show the relation between the potential pattern and geometry.

The theoretical potential pattern in an electrolyte surrounding a pair of coupled line electrodes having different polarities was compared with the potential configuration around an infinitely long cylinder, to which uniformly distributed direct current is flowing. By superimposing the coupled line electrodes longitudinally on the diameter of the cylinder, the effective electrical boundary applicable to the combination can be expressed geometrically. The location of the electrical boundary was confirmed experimentally by comparing potentials measured between model galvanic couples and a reference electrode in a surrounding electrolyte with calculated boundary potentials based on the measured electrode surface potentials and electrolytic *IR* drops.

By using electrical insulating shields, the effects of non-uniformly distributed current on the potential patterns around the model galvanic couples were studied. The position of the reference electrode, under such conditions of interference which resulted in measured potentials having the most significance, was arrived at experimentally. The insulating shields simulated the effect of the ground surface on pipelines.

As a result of these experiments, when making potential measurements, for example, pipe-to-soil, during line-conditioning surveys or when applying the protective potential criterion for cathodic protection, it is recommended that the reference electrode be placed 4 to 6 pipe diameters from the line, at some distance below the earth's surface and preferably in an approximately horizontal position with respect to the pipeline.

HYDRAULICS

An Investigation of Hydraulic Lock.

By J. MANHAJM and D. C. SWEENEY. (From a paper presented at a meeting of *The Institution of Mechanical Engineers, London*, May 13, 1955, 12 pages, 15 illustrations.)

HYDRAULIC lock is a phenomenon encountered in piston-type control valves governing the supply of high-pressure oil to mechanical equipment. It is liable to occur when conditions are such as to produce an axial pressure gradient in the fluid contained in the clearance space surrounding the piston lands, and its

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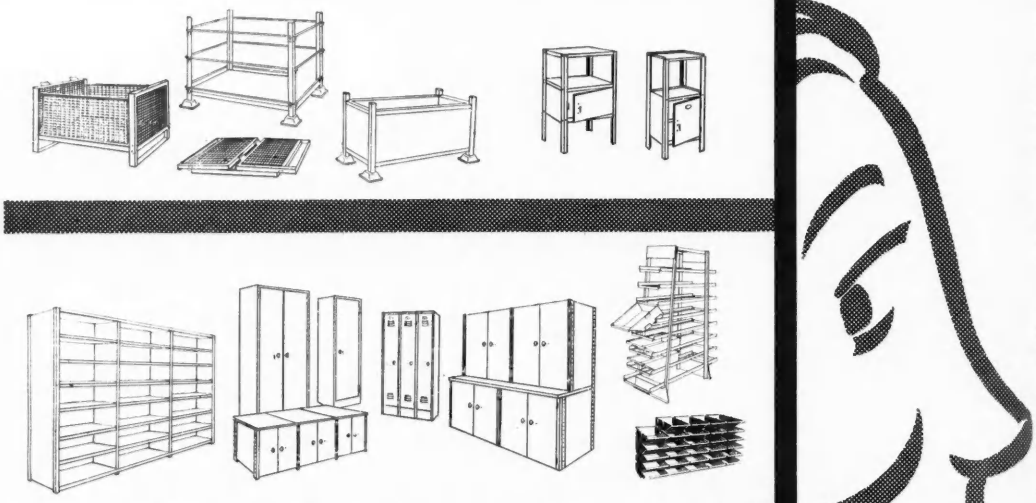

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effect is to cause sticking or locking of the piston in its enclosing cylinder.

Preliminary investigations have indicated that true hydraulic lock is essentially a hydrodynamic effect, resulting from asymmetric pressure distribution in the clearance space between piston and cylinder. Thus, if the flow of fluid in the clearance space is either diverging or converging, an asymmetric distribution of pressure will in general result and will be accompanied by a transverse thrust on the piston. If the clearance is divergent in the direction of flow, the piston will be forced against the cylinder wall; if convergent, the action of any thrust arising will be to exert a centralizing effect.

This paper deals with an extension of the investigation referred to above, the object being to examine, both theoretically and experimentally, the effect on hydraulic lock of the employment of tapered piston lands. For this purpose, a mathematical analysis was made of the pressure distribution in the clearance space between piston lands and cylinder bore and of the accompanying side forces on the piston for a range of selected conditions. To establish the validity of the analysis, experiments were carried out on a cylinder of uniform bore in conjunction with dumbbell-shaped pistons having lands of such form as to give various taper-clearance ratios. In general, the procedure was as follows :—High-pressure oil was supplied through the cylinder wall to the annular space between the two lands of the piston, the oil then flowing outwards in both directions through the clearance space. Pressure tappings at a number of points in the cylinder wall permitted the pressure distribution in the clearance space to be determined, and suitable provision was made for the measurement of any locking force acting on the piston.

The results of the theoretical analysis, which are closely confirmed by experimental evidence, lead to the conclusions that (1) hydraulic lock under the conditions considered is a purely hydrodynamic phenomenon; (2) unless the piston and cylinder bore are truly cylindrical, or the axes are exactly coincident, a non-uniform distribution of pressure is produced in the clearance space, giving rise to an unbalanced transverse thrust acting on the piston; (3) if the clearance space diverges in the direction of flow, the direction of thrust will be such as to force the piston against the cylinder wall. If it converges in the direction of flow, the thrust will have a centralizing effect, any tendency to lock being thereby eliminated; (4) the form of the pressure distribution, under given conditions, and hence the side thrust and locking force on the piston, may be determined mathematically; and (5) a linear relation exists between locking force and the difference in fluid pressure at entry to and exit from the clearance space, provided that there is no appreciable distortion of the components.

INSULATING MATERIALS

Thermal Stability of a New Insulating Material used in Traction Motors.

By R. W. FINHOLT. (From *Applications and Industry, U.S.A.*, No. 17, March 1955, pp. 37-41, 7 illustrations.)

MODERN traction motors operate under severe conditions. The latest standard adopted for traction motors provides that the peak value by resistance of the armature shall not exceed 160° C, and that the peak value for the fields shall not exceed 170° C. Modern traction motors on heavy diesel-electric locomotives often exceed these temperature limits by 20 to 30° C. The temperatures in the hottest part of the armature and the hottest part of the field will exceed these average resistance measurements. Coupled with these high temperatures are severe vibration conditions, dust, water, varying humidity, highly variable maintenance, and shock. The majority of traction-motor equipment operates on 3000 V or less on direct current, or 1500 V or less on alternating current.

A general problem in insulation is that of high temperature, combined with a number of mechanical destructive factors. In the search for better materials, tests have been run on the high-temperature materials which have become available in the last 15 years. One of these in particular has proved to have such excellent properties, both physically and economically, that it is being widely adopted for use on traction motors. This new material is known as mica mat, and the results of tests on the thermal stability of mica mat impregnated with silicone resins are described in this article. This silicone-impregnated mica mat is available as a 4·5-mil sheet material, and also as a 5-mil glass-backed tape in widths up to 38 in.

As in the testing of all traction-motor insulation, the effect of heat alone was only a small part of the investigation necessary. The effects of heat in combination with humidity, with pressure, and with vibration were of equal or perhaps even greater importance than the effect of heat alone. The combination of all these effects was studied in a series of life tests and field tests of motors under operating conditions. Although quite suitable at high temperatures and low pressures, the material is inadequate if the equipment must withstand high pressures.

Classification of a material like silicone-treated mica mat can be reasonably carried out only on the basis of use. The question is whether it will stand up to the purpose for which it is designed. Electrical design engineers must consider each case separately on its merits, as they cannot depend on an overall heat-type classification to tell whether a material can be used or not. In traction-motor equipment, mechanical effects are extremely important; indeed, in the case of many insulating materials tested, they have been found to be limiting factors.

IRON AND STEEL

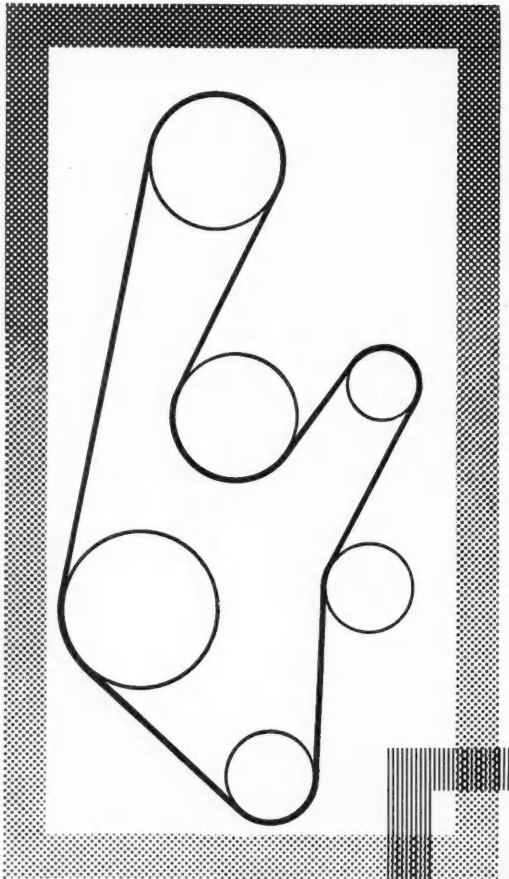
The Nominal Cleavage Strength of Steel.

By T. NOREN. (From *Jernkontorets Annaler, Sweden*, Vol. 139, No. 3, 1955, pp. 141-153, 11 illustrations.)

THIS article describes investigations in which a brittle alloy was welded onto the edges of flat tensile testpieces of several soft steels. On exposing such testpieces to an increasing tensile stress, fresh cracks were continuously formed in the brittle surface layers. At a certain critical stress a crack which has formed will continue into the steel, and a brittle fracture is obtained.

It is shown that a characteristic property of steel is the nominal cleavage strength, which may be defined as the highest nominal tensile stress a steel can maintain in the presence of a fracture without the crack propagating. The nominal cleavage strength decreases continuously as temperature decreases in the same way as the conventional yield point increases continuously with decreasing temperature. The point of intersection of these two curves would appear to be a transition temperature for the steel and may be defined as the temperature above which deformation can occur in a large volume of material, despite the presence of a crack, but below which only local plastic deformation immediately in front of the crack is possible.

A certain correlation to Charpy V-notch impact tests has been found if the steel plate tested is of about the same thickness as the impact test bar. With thick material, Charpy V-notch impact tests generally show such a large scatter that difficulty is found in making a comparison between the position of the impact-strength curves and the transition temperature found in connection with the nominal cleavage strength. Under certain conditions the impact test may give too optimistic a view of the properties of the material.



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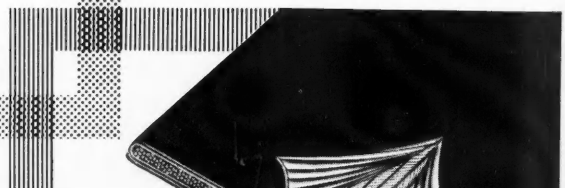

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MAGNETISM

Calculation of the Magnetic Field in the Ferromagnetic Layer of a Magnetic Drum.

By O. KARLQVIST. (From *Acta Polytechnica, Sweden*, Electrical Engineering Series, Vol. 6, No. 1, 1954, 27 pages, 16 illustrations.)

IN this paper, the field in the ferromagnetic layer and the variation of this field with permeability, airgap, layer thickness, and other influencing factors are studied. The problem is definitely non-linear and extremely difficult to solve, but the linear case gives a first approximation, which in some cases seems to be satisfactory. Here, the linear boundary-value problem for the two-dimensional static field and the one-dimensional transient field is solved.

The magnetic field in the ferromagnetic layer on a magnetic drum is calculated as having finite airgaps in the recording head and finite permeability in the layer. The layer is assumed to be a spinel material for which the permeability is low. The special cases when the permeability is one and infinite are treated by conformal mapping. The results from this investigation suggest a linear potential distribution between the corners of the recording head. This approximation gives explicit expression for the field, and the method is generalized to finite permeability.

Expressions are given for the field on each side of the layer, and asymptotic expressions are given for the field at a large distance from the pole gap of the recording head. The inductance of the head is calculated, and measurements of the inductance change have been made when the permeability is increased from 1 to μ. The transient field is computed for the one-dimensional case, assuming the resistivity of the layer to be very large. The results can be used to analyse the influence on the field from the permeability and from the geometric shape of the head.

PLASTICS

Recent Developments in the Use of Plastics in the Foundry.

By P. G. PENIX. (From a paper presented at the *British Plastics Convention, London*, June 2 to 9, 1955.)

IN the use of synthetic resins to bond sand for making solid foundry cores, new developments are to be found mainly in refinements of the resins and in methods of securing rapid cure, thus taking full advantage of the intrinsic properties of these thermosetting materials.

Hollow-shell cores with many advantages over solid cores are coming into prominence as an offshoot of the shell-moulding process, being made possible by the advent of non-segregating (precoated) resin-bonded sand. Various methods and specialized equipment have been developed for making shell cores, using simple dump/shake-out, blow/suck, or limited-blow techniques. Economies are obtained in material costs, production time, and fettling costs (through improved casting finish); consequently, a rapid extension of shell-core production is envisaged. Resins used for this purpose are almost entirely of the phenolic type, but include both resoles and novolacs with hexamine.

The use of such resins in precoating sand for shell moulding has received much attention. Several methods of precoating sand have been proposed, but only the F.E.L.L. process has been used on any substantial scale in Britain. Advantages of precoated sand for use in making shell moulds, in addition to the obvious absence of segregation which the term " precoated " implies, are discussed in relation to alternative shell-moulding materials. The rapid development of shell moulding in British foundries during the last year or two is attributed to the availability of automatic or semi-automatic shell-moulding machines, a clarification of the patent position, and the wide dissemination of knowledge and experience through the foundry industry—a process in which there can be no doubt that the plastics industry has played an important part.

The translation of shell moulding from semi-laboratory development work to full-scale production has brought into focus problems which were previously unrecognized, except perhaps in the U.S.A., where the process came earlier into large-scale use. Minor differences between grades of resin are becoming significant through their influence on such production variables as investment and curing cycles. Health problems associated with dust from the fine silica sand, and to a lesser extent the powdered resin, claim serious attention, and point to the substitution of the apparently innocuous precoated sand, wherever possible. The need for recovery and re-use of shell-moulding sand has become apparent in consequence of the limited availability of new sand in the quality required. More rapid and flexible methods of securing half-moulds are needed to meet varying production conditions.

Among the smaller applications of plastics in foundry work is the use of thermosetting resins. Furane resins have been found surprisingly inferior to phenolics for this purpose, but their outstanding heat resistance has been put to good use in making cheap core carriers for moderate runs. The possibility of casting patterns in furane resin compositions is being explored with a view to their use in place of metal patterns for shell moulding on short runs. For patterns and coreboxes used cold, cast epoxide resins hold great promise and are being actively investigated.

PRESSURE VESSELS

Plastic Fatigue Properties of High-Strength Pressure-Vessel Steels.

By J. H. GROSS and R. D. STOUT. (From *The Welding Journal, U.S.A.*, Vol. 34, No. 4, April 1955, 161s-166s, 11 illustrations.)

THE general purpose of the investigation described in this paper is to provide information on the fatigue resistance which may be expected from pressure-vessel steels when cycled under loads high enough to cause plastic flow, such as might occur at stress-raisers present in a pressure vessel. Of particular interest in this connection are the high-strength steels which are under consideration for use in pressure vessels. In order to gain the full benefit of these high yield-ratio steels, it is necessary to allow a design stress which is, say, half the yield strength, and therefore as much as 45% of the tensile strength. At a design stress of this level, assurance is needed that no failures are likely to be induced by fatigue.

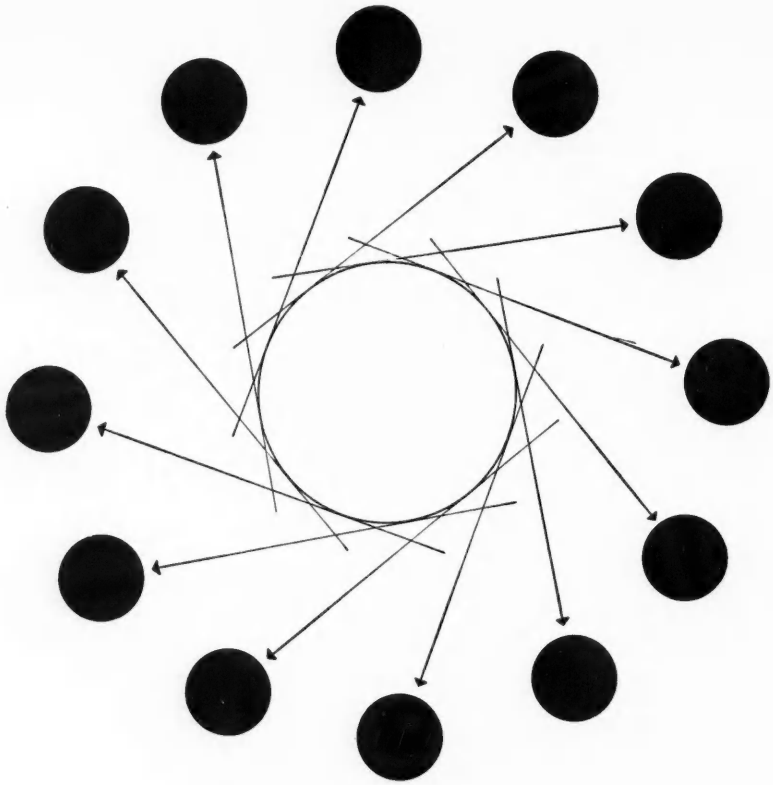
The performance of six representative high-strength steels in plastic fatigue tests is reported in this paper. The results of this investigation can be summarized as follows :—

(1) For a fatigue life of 100,000 cycles, the allowable straining range increased as the tensile strength of the steel was raised from 60,000 to 120,000 psi.

(2) Welding had a negligible effect on the fatigue resistance of the high-strength steels investigated, when the reinforcement was removed. Notching lowered fatigue life in all steels but not as severely as would be expected from the stress-raising factor.

(3) From the viewpoint of fatigue, carbon steel can be design-loaded to a higher fraction of its yield strength than can the higher-strength steels (when stress-raisers with a factor of 2 and a life of 100,000 cycles are assumed). Tensile strength rather than yield strength seems to control fatigue resistance in these steels.

(4) When the testing temperature was raised from room temperature to 650° F, both A-201 and A-302 steels showed higher plastic fatigue resistance at all levels of straining range.



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(5) A change in cycling rate from 200 to 1·5 cpm lowered the fatigue life of both A-201 and A-302 steels by about 10 to 15%. Thus, some allowance might be necessary in service for conditions involving very low cycling rates.

(6) The results reported are for comparative purposes rather than for quantitative evaluation of service fatigue life. They are believed to be valid for studying the effects of variables important to plastic fatigue.

STEAM TURBINES

The Reversible Bending of Turbine Shafts with Temperature.

By A. BARKER and F. W. JONES. (From a paper presented at a meeting of *The Institution of Mechanical Engineers, London*, May 6, 1955, 8 pages, 9 illustrations.)

IT has been known for some time that some steam-turbine shafts can bend when heated (Weaver, 1941). Three types of bending have been recognised by Caplan, Jolley, and Reeman (1947). The first is transient and occurs only when the temperature of the shaft is changing, the deflexion being zero when the shaft is at a steady temperature. This can be accounted for by emissivity variations around the surface of the shaft and lack of black-body conditions. The second type of bending occurs with new shafts, which on heating up deflect permanently, this deflexion remaining on cooling to room temperature. This is due to relief of residual stresses which are not axially symmetric, and on subsequent heating no further deflexion occurs. In the third type of bending, the shaft deflexion is proportional to the temperature of the shaft when this is steady. Thus, the shaft bends when hot and is straight when cold. The latter type of deflexion is considered in this paper. It has been suggested that this type of deflexion could be explained by chemical segregation which is not axially symmetric and which would result in variations in expansion coefficient in the same pattern as the segregation. Tests have been carried out in collaboration with Caplan and Jolley to verify this. Carbon-steel shafts of the dimensions normally used for built-up turbine rotors were deliberately produced in such a way that the position of the chemical axis of the shaft was a significant distance from the geometrical axis. This asymmetry was considered to be greater than would occur in practice. The effect on the thermal stability of the shafts was measured and was either zero or small.

The conclusions derived from this investigation are as follows :—Heat-indication experiments have shown that some carbon-molybdenum steel shafts can bend when hot and become straight again when cold. This effect, in the case of two shafts examined, has been shown to be due to a difference in expansion coefficient in the steel on opposite sides of the shafts; also, this difference in expansion coefficient is not caused by chemical macro-segregation but is a result of non-uniformity of heat treatment—in this case, in normalizing and austenitizing prior to normalizing.

A change in expansion coefficient of the correct order of magnitude has been produced in two different casts of carbon-molybdenum steel, one having a higher nickel content than the other.

The change in expansion coefficient in a given specimen has been shown to be reversible by using the appropriate heat treatment, and a shaft which was originally defective has been corrected by re-treating in such a manner that all parts of the body of the shaft transform in the same manner.

In general, a bainitic transformation results in a high expansion coefficient and a pearlitic transformation in a low expansion coefficient. Longer tempering times increase the expansion coefficient of bainitically transformed specimens and have little effect on pearlitically transformed specimens.

Improved Radiographs by means of Tungstate Intensifying Screens

(*Concluded from page* 272.)

Wire-detail detection as a function of thickness of steel irradiated for a tungstate screen is shown in Fig. 2, for voltages from 90 to 135 kV. The percentage detail obtained with tungstate screens is more favourably situated in the entire range investigated up to 40 mm of steel. By using extra-fine-grain films, it is possible to obtain (with, however, reduced sensitivity) values between 0·6 and 0·8% with, for instance, 20 mm of steel.

It should be noted that the results described above for fine-detail tungstate screens and screenless films can be still further improved in the range used in medical work (i.e., below 100 kV). The improvement is even more marked in the lower voltage range of materials testing (100 to 150 kV) and in the medium and upper range (150 to 300 kV). In these ranges, the sensitivity of the tungstate screen, with practically the same degree of detail detection as the lead sheet, permits a much greater reduction in voltage to be obtained.

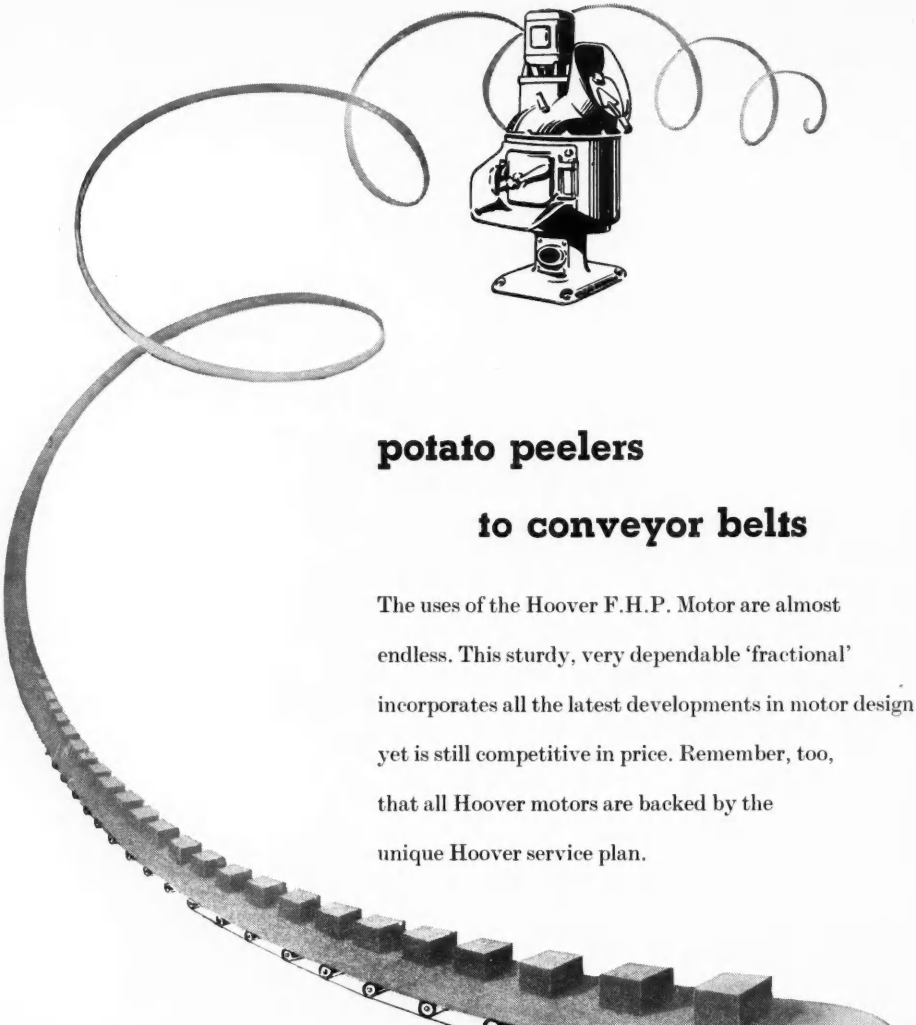
A good criterion (apart from penetrometer tests) is the amount of detail which can be detected in fine cracks in a material. For instance, a cast-steel flange was found to have fine surface cracks (to a maximum depth of 2 mm), which extended in a direction at an angle to the direction of the rays. These cracks had been revealed by the magnetic powder method. Lead-sheet recordings showed these cracks to be blurred and indistinct, so that, if their position had not been known, they might easily have been overlooked. Radiographs with a fine-detail screen and screenless film, on the other hand, clearly revealed the fine details of the course and structure of these cracks.

COMPARISON WITH SCREENLESS RECORDINGS

Further evidence of the extent of improvements noted was demonstrated by comparing radiographs taken with and without tungstate screens. Using the same voltage, little difference in sharpness between screenless and screen recordings on the same screenless film can be found. In practice, however, the greater sensitivity (approximately 8 times) obtained with a screen permits a reduction in voltage. For instance, with a 10-mm steel the reduction is from 105 kV to 90 kV (with 30 mA-min in both cases), and no difference in sharpness can be distinguished. Percentage wire detail is the same in both cases, i.e., about 1 to 1·2%. Thus, the fine-detail tungstate screen can also successfully replace the screenless set-up for thicknesses below 10 mm, whereas, in most cases, it was not possible previously to go below 15 mm. In these applications, the reduction in voltage again compensates for the slight reduction in definition of the screen; details stand out in greater relief and with more brilliancy.

It is of interest to note the difference in exposure required for recordings with and without screens on screenless film. Whereas for medical work in the range of 50 to 70 kV the time with a screen can be reduced to one-quarter of its original value, the difference becomes considerably greater with the voltages employed for materials testing, and the exposure can be reduced to one-eighth for the same voltage.

The intensifying effect of lead-sheet combinations of 0·02/0·02 mm with a 23-mm thickness of steel is at most 3:1. Other lead thicknesses, and also gold-plated lead sheet, are no better. The value for tungstate screens with screenless fine-grain films under the conditions described above is about 8:1. The intensifying effect of the same tungstate screen with a sensitized normal screen type of film is of course considerably higher (about 20:1), but this is not directly comparable, since the direct influence of the X-ray radiation on this film is much smaller.



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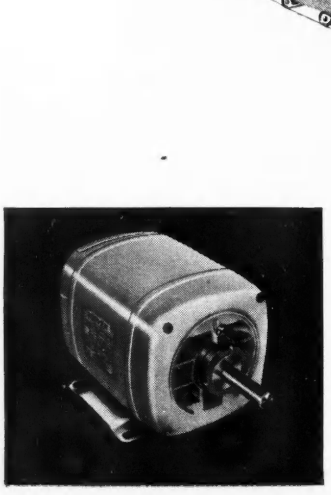

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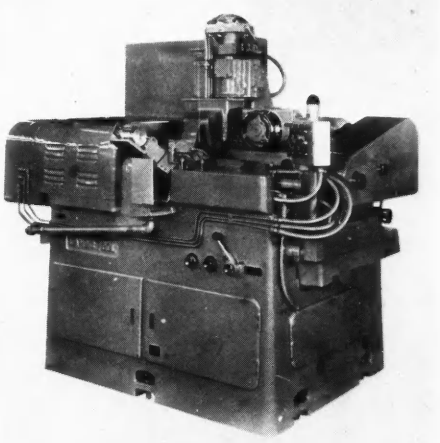
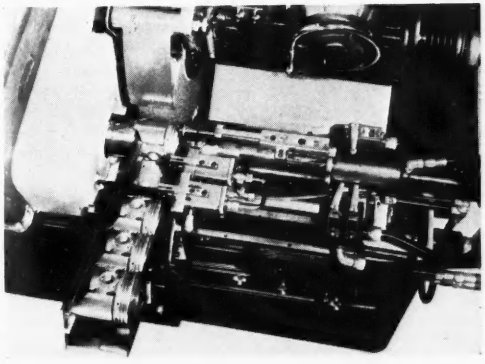
AUTOMATIC PISTON GRINDER

The Landis Tool Company of U.S.A. have produced a new grinding machine which speeds up the production of internal combustion engine pistons and at the same time reduces grinding costs and improves the quality of the product. Messrs. Burton, Griffiths & Co. Ltd., of Birmingham, are the sole selling agents for this and all other Landis machine tools in Great Britain.



This new 5 × 8 in. type H precision grinder automatically loads, grinds, and discharges pistons. The aluminium-alloy pistons can be delivered to the machine by conveyor and transfer mechanism. An automatic timed loader places the piston in the grinding position. Rotation begins as the grinding wheel advances rapidly to the grinding position. Slow grinding feed then proceeds to a positive, predetermined size. After a timed spark-out period, the grinding wheel retracts rapidly to a back position and the piston is ejected onto another conveyor. Simultaneously, another piston is loaded and the cycle is repeated. The pistons are ground by the infeed method, using a wide wheel, which reciprocates laterally during the grinding cycle. The elliptical shape of the pistons is produced by using a master cam and rocking work cradle.



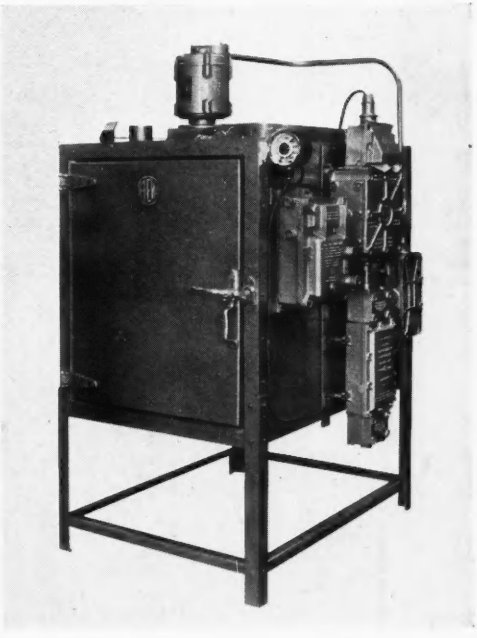
Wheel dressing is automatic after a predetermined number of pistons are ground. The wheelhead automatically advances the same amount as the size of the wheel is decreased by dressing. This eliminates compensation by hand to return the wheelhead to the correct position for proper size.

The machine is fitted with microsphere bearings for both the workhead spindle and the grinding-wheel spindle. These bearings are of one-piece steel construction, with babbitt lining faces. The spherical shape permits perfect alignment to the spindle and adjustable running clearance. Lubrication to the bearings is automatic.

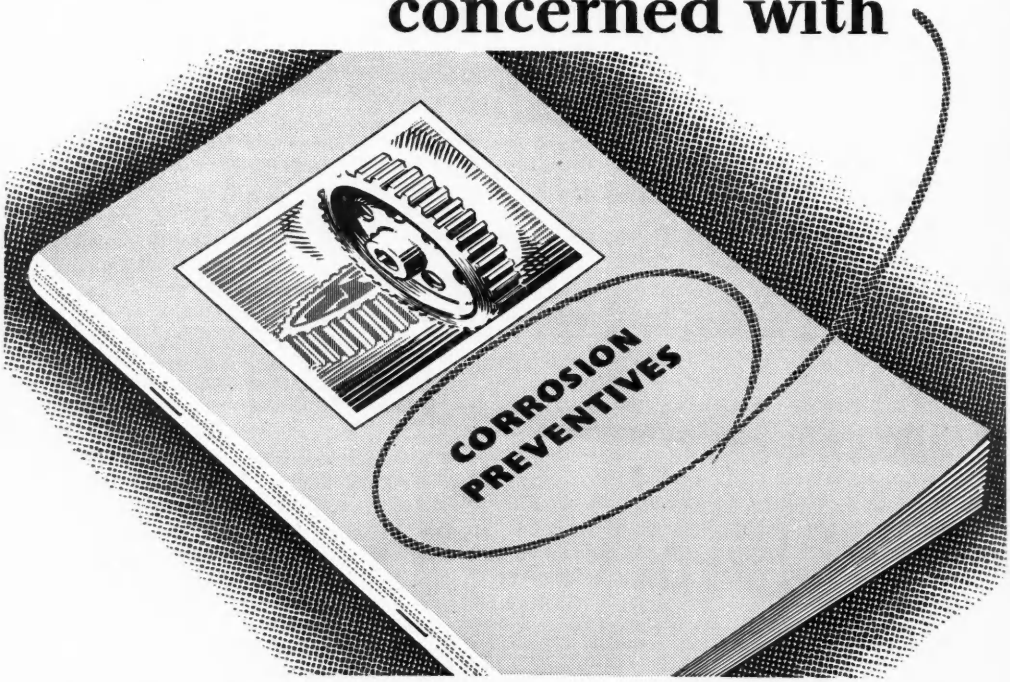
OVENS SUITABLE FOR BUXTON GROUP-2 GASES

The range of intrinsically safe ovens suitable for Buxton Group-2 gases, manufactured by A.E.W. Limited, of Edgware, Middlesex, features robust, double-cased construction, with high-thermal insulation between inner and outer case, and heavy sealed insulated doors hung on heavy malleable-iron hinges. Replaceable metal-sheathed elements, with special termination fittings outside the oven in flameproof boxes, are rated so that their surface temperature is only slightly in excess of the working temperature of the oven. Temperature is controlled by a thermometer regulator in circuit with a specially adapted relay, to reduce the contact load to a safe wattage. A safety thermostat is fitted in the same circuit to limit the temperature rise of the heating elements and, should the thermometer fail to act as a proportioning device, to stop temperature overshoot of the oven.

A powerful impeller fan driven by a flameproof motor is fitted in the top of the oven chamber, and both



This Book is important to all concerned with



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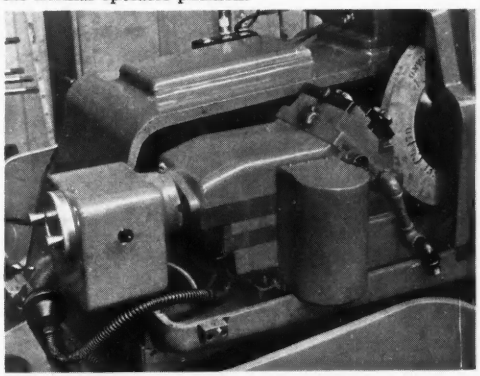
exhausts and recirculates air in the oven. Air is drawn from the oven chamber, is forced over the heating elements, and returned to the oven chamber. Air exchange is regulated by an adjustable vane in the outlet duct and is variable from 1 to 5 air exchanges per minute or more. Fresh air, equal to the amount expelled, is sucked from the atmosphere and thoroughly mixed with the circulating air before being passed over the heaters and into the oven work-chamber. The fan-motor and heater-control circuits are interlocked, so that the heating elements cannot be switched on without the fan; in the event of motor failure, the heaters will be switched off. To avoid a concentration of gases when the oven has been closed down for loading with fresh work, a device is incorporated whereby the heating elements will not switch on until the fan has been running for 3 minutes.

An explosion-relief vent of an improved pattern is built into the roof of the oven, and consists of a thermal-insulation aluminium-foil blow-out panel on a light aluminium frame resting on seals. In the event of an explosion, the foil is free to burst and the frame to rise off its seating, being limited in its movement by safety chains. In smaller ovens, where there is insufficient room to fit a vent in the roof, an aluminium-foil blow-out panel of the conventional pattern is fitted in the side. All electrical control gear and mains isolators are in flameproof housings.

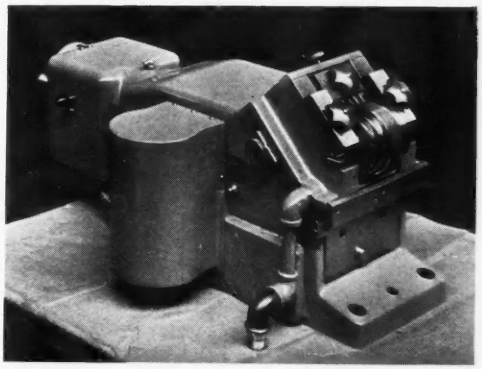
AUTOMATIC POWER-OPERATED CRUSHING ATTACHMENT

Recently introduced by the Newall Engineering Company Ltd., of Peterborough, for employment with their model "N.L." (Type D) thread grinder, for production grinding of components, is the automatic wheel crushing device illustrated below. The attachment, which is available as additional equipment, is rigidly mounted on a machined base at the rear of the grinding wheel, but is operated by remote control from the normal operator position.



The spindle is mounted in two hardened and ground Vees and is held in position by clamps. The crusher roller, which may be laterally adjusted, is carried on a drum rotating on two precision, dual-purpose bearings about the spindle, and is retained by a threaded collar.

A fitted brush sweeps any adhered grit from the roller, which is, in addition, washed by an internal jet of coolant. Illustrated below is a front view of the device, showing the mounting of the crusher roller. The slideways, fitted with taper gibs, which may be adjusted by flanged screws to the rear of each slide, are connected by internal channels and, together with the feed screw, are lubricated from oil nipples. Lubrication to the crusher roller bearings is fed from a grease nipple. Crusher feed is applied by operation of a press button, each depression of which gives a feed of 0·001 in., the maximum recommended feed per cycle being 0·004 in.



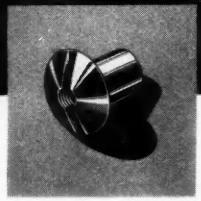
An outstanding feature of the new device is the simple and short sequence of operations necessary for crusher forming of all types of thread, concave, and convex forms. This sequence merely involves stopping the grinding wheel, applying the amount of feed required, starting the crusher (the complete cycle takes one minute), and starting the machine for grinding. Fast and accurate in operation, the attachment may be used without removal from the machine of a component set up for grinding, and the only extra equipment necessary is a special planetary pulley, through which the grinding wheel is driven.

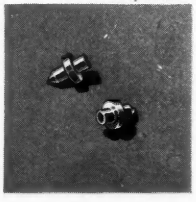
ELECTRONIC GRINDING INDICATOR

The act of grinding involves the tearing away of particles of metal by the harder particles of the grinding wheel, resulting in the generation of instantaneous local heat. This heat is prevented by flooding the work with coolant, which must not be turned off while the operator is making contact between the grinding wheel and the work; consequently, the operator is unable to hear or to see when this contact has been established with the necessary degree of precision. The "Morrisflex" electronic grinding indicator, manufactured by B. O. Morris Limited, of Coventry, overcomes this difficulty neatly and accurately.

The instrument comprises a cathode-ray tube excited through a vibration pick-up, which is mounted on the grinding machine in such a position that the instant the grinding wheel touches the work the resultant vibration shows on the tube as a brilliant Vee. The operator can, therefore, very accurately pick up his point of contact after redressing the wheel or after similar operations. The cathode-ray tube and electronic apparatus are enclosed in a box, measuring only $6 \times 4\frac{1}{2} \times 13\frac{1}{2}$ in. The instrument, which weighs 12 lb, responds to a frequency from 4 to 30 kc/s, and is mains-operated, normal voltage being 200 to 250 V, though it can be supplied for other voltages.

The instrument can, of course, be used for any





Insets above and below illustrate parts enlarged approximately two and a half times.

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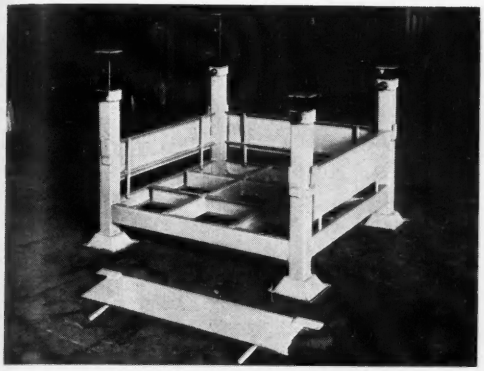
desirable vibration pick-up, not necessarily connected with grinding. Thus, for example, it can be used for the breaking through of a drill when drilling deep intercepting oil holes, or as an indication of impending bearing failure. An additional application could be that of inspection to given vibrational standards.

ADJUSTABLE PILLAR-TYPE STILLAGE

To comply with the ever-increasing demand for lowering the costs of handling materials and improving the storage facilities of finished products, A. E. Griffiths (Smethwick) Ltd., of Birmingham, have produced an adjustable pillar-type stillage. Two sizes of this stillage have been constructed, to suit requirements of manufacturers, and further adaptions are being considered in the aero- and motor-engine industries.



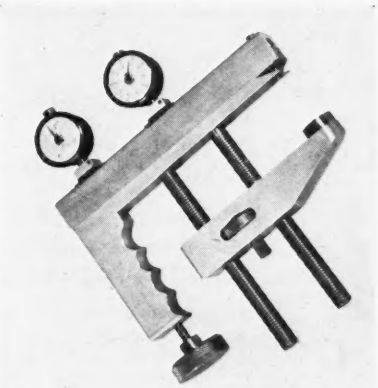
It has been realized that components of irregular shape and size are difficult to handle and store in uniform sequence, but, with this new type of extending-pillar stillage, any shape of product can be accommodated and stored, one above the other to a reasonable height, quite safely. Two types can be supplied, i.e., open-sided, and with detachable sides (illustrated). Both types can be constructed with plate decking, if desired.

PORTABLE HARDNESS TESTERS

Two new models of portable hardness testers have been developed by the Riehle Testing Machines Division of American Machine and Metals, Inc., of East Moline, Illinois. These new units, Model PHT-1 with a capacity of 4½ in. diameter or thickness, and Model PHT-2 (illustrated) with a capacity of 12 in. diameter or thickness, employ basically similar operating procedures and are designed to test parts inaccessible to bench-type hardness testers. They can be used for production testing of crankshafts, cylinder blocks, assemblies, and similar pieces; they can test both inside and outside surfaces of tubing, pipes, castings, bushings, ball-bearing races, and other difficult pieces, and can be used vertically, horizontally, or at any angle.

These new hardness testers are ready for instant use; no set-up time is involved, and they can make tests without sectioning of specimens. Operation is simple and a standard diamond indenter with standard Rockwell loadings is used. There are no errors due to conversion from other scales to Rockwell hardness numbers. Two contact points touch the surface of the specimens to establish a measuring reference. If the surface moves as a result of crushing of scale and dirt against the anvil, or as a result of specimen deformation, the reference moves a similar distance. Thus, there is a zero net effect on the hardness measurement.

When testing with a bench-mounted Model PHT-2, there is no need to raise the specimen once it has been placed on supports. The indenter moves down to meet the specimen. This feature eliminates errors and broken



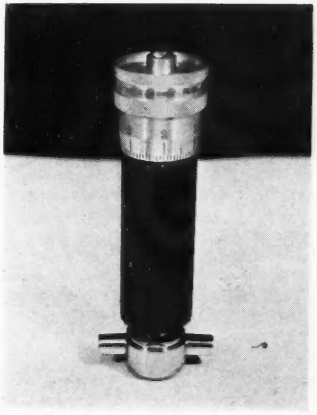
indenters caused by the unavoidable lateral motion resulting when a specimen is not raised uniformly on all supports.

Large dials are easily read without magnifying lenses. Dial markings are in standard red and black for rapid identification of Rockwell scales. A single knurled screw holding the indenter shanks facilitates changing indenters as different Rockwell scales are required. The specimen is held fast by a clamp, freeing the indenter for hardness measurement alone. Since the indenter does not serve as a clamp, there is a reduced possibility of indenter breakage or out-of-round set on ball indenters. A lever ratio permits fingertip loading, even up to 150 kg. Both models can be arranged for either left- or right-hand operation, or with dials at specified angles to the plane of the instrument.

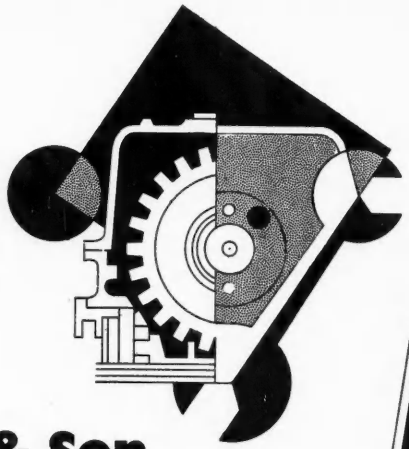
PEAK-PRESSURE INDICATOR

The peak-pressure indicator shown by Dobbie McInnes Ltd. of Glasgow, at the recent Physical Society Exhibition was devised as a ready means of checking the maximum cylinder pressure of internal combustion engines. Readings are shown automatically on a graduated sleeve, and can be in pounds per square inch or kilogrammes per square centimetre, the normal pressure range being 300 to 1400 psi.

Where it is impracticable to use a shut-off cock, the peak-pressure indicator can be supplied with a water-cooling arrangement. It can also be produced in a modified form for indicating pressures in the fuel lines of diesel engines, the pressure range being up to 10,000 psi or more.



Smith's for Technical Books



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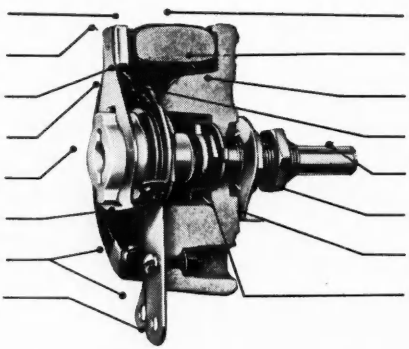

1 Silver graphite brush contact
2 Balance point for self-aligning brush
3 Pig tail shunting brush arm
4 Nickel silver brush arm
5 Glazed porcelain brush arm insulator
6 Winding welded to terminal band
7 End contact band and terminal
8 Brush terminal
9 Winding embedded in vitreous enamel
10 Vitreous enamel bond between former and base
11 All ceramic construction withstands 5000v. flash test
12 Non-grooving return contact plate
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PILLAR-TYPE MEASURING MACHINE

To meet the ever-growing need for accurate measuring machines in the rope, rubber, electric-cable, and plastic-extrusion industries, B. & F. Carter & Co. Ltd., of Bolton, offer a pillar-type measuring machine with many advantages. This is mounted on a pillar, as shown in the illustration, of any suitable height to permit the free passage of material to be measured through the measuring wheel and the spring-loaded jockey wheel.

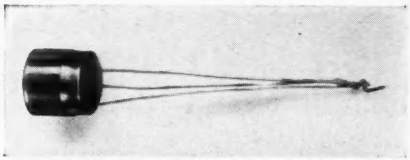
The machine is fitted with a measuring wheel of patented design, one yard in circumference, consisting of a thin, hardened-steel tyre stretched over a layer of sponge rubber; this provides a resilient surface to the wheel, thereby presenting a flat to the material to be measured and minimizing the possibility of slip, as encountered with the usual point-contact wheels. The resilient measuring wheel imposes very little tension on the material to be measured; as a result, any possibility of damage is eliminated and, at the same time, very high measuring speeds can be obtained.

The measuring-wheel spindle is mounted on ball races and drives an "Albion" 5-figure revolution counter with a patented roller zero-setback motion, to record in either feet or yards. In addition, a tachometer is provided, to register linear speed in yards or feet per minute. This is of great value in cases where it is necessary to check output for the purpose of ensuring that the parent unit is operating at the desired speed. This dual-purpose machine provides a double check, giving accurate and rapid information at a glance, inasmuch as the bold figures on both the counter and the tachometer can easily be read from some distance.

HIGH-FREQUENCY POINT-CONTACT TRANSISTOR

A new high-frequency germanium point-contact transistor, known as type EW51, has been developed by the General Electric Company Ltd., of London. Its main value is in pulse circuits (e.g., amplifying, forming, and shaping of pulses) and it is therefore of considerable importance in the field of digital computers. Used as a pulse amplifier, its speed of response is such that, if the rise time of the input waveform is 0·05 microsecond, the rise time of the output waveform is less than 0·15 microsecond (usually less than 0·10 microsecond).

If the input waveform does not cause the transistor to "bottom" (a condition of high collector current and low collector voltage, in which further increase in the amplitude of the input signal does not increase the amplitude of the output signal), the fall time of the output waveform will be approximately equal to the rise



time. If bottoming occurs, the fall time will be increased because of the "hole-storage" effect; the actual increase will depend on the degree of bottoming and the duration of the pulse.

The spacing between the metal whiskers at their points of contact on the germanium surface is extremely small (approximately 0·001 in.). This has been achieved by paying particular attention to the mechanical construction of the transistor; as a result, it can withstand considerable mechanical shock and vibration and can also be stored at temperatures of up to 70° C without change in characteristics. The transistor is hermetically sealed in a metal container, measuring $\frac{3}{8}$ in. in diameter and $\frac{3}{8}$ in. in length. It has successfully withstood a test in which it was cycled daily for 84 days to an elevated temperature in a very humid atmosphere.

The device has a number of interesting electrical features. Thus, it "bottoms" at a collector voltage of the order of 1 V; this is advantageous in circuits operated from a low d.c. supply voltage. The "off" collector current (i.e., the current flowing at a given collector voltage when the emitter current is zero), although slightly higher than in some types of point-contact transistors, is almost independent of temperature over the allowed range of operating ambient temperature. Increasing the ambient temperature from 20° C to 50° C causes the "off" collector current to increase by only about 10%.

Stress Corrosion of Stainless Steels

(*Concluded from page* 290)

also applies to the stainless steels. The exception to this is the intergranular failure associated with poor structural condition of the metal. Applied stress, either static or the dynamic stresses resulting from thermal or mechanical fluctuations, may intensify residual stress.

Recently, Edeleanu[9] suggested that the transgranular stress-corrosion cracking in austenitic stainless steels is due to preferential attack on small quantities of quasi-martensite, which form in the steel during straining. However, evidence of stress corrosion in types 309 and 310 stainless steels, which show no tendency to form quasi-martensite, suggests that this phenomenon alone is not responsible.

Generally, stress corrosion of stainless steels is believed to occur only in environments containing chlorides. This belief has some support, inasmuch as practically every environment in which cracking has occurred has contained at least a trace of chlorides. Nevertheless, failures have been reported in molten sodium hydroxide, sulphuric acid, and moist hydrogen sulphide, which contained no chlorides. Undoubtedly, these environments also cause a localized breakdown in the protective film, similar to that caused by the chloride environments.

Briefly, stress-corrosion cracking can occur in stainless steel when it is subjected to a sufficiently high stress and simultaneously exposed to an environment whose nature causes localized attack. Stress corrosion has not been observed in those environments which cause rapid general attack. Therefore, like pitting and intergranular corrosion, stress corrosion appears to be associated with a localized breakdown of the protective film, and this breakdown is accelerated by applied or residual stresses.

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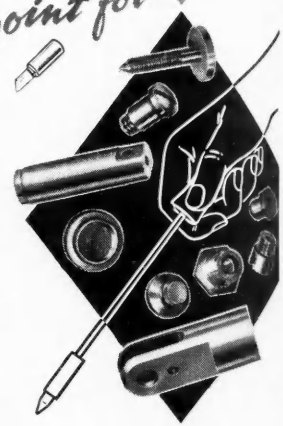

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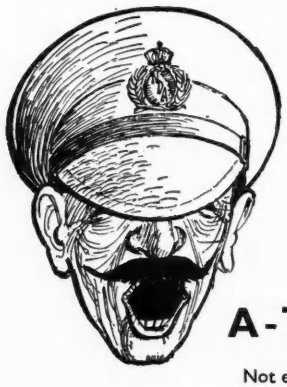

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NEWS OF THE MONTH

PERSONAL

Mr. R. W. Bassil, A.M.I.E.E., has been appointed superintendent of the Deptford West generating station of the Central Electricity Authority, to succeed **Mr. G. H. Whelton,** who retired this month.

Mr. R. C. Bloxham, manager of Dunlop overseas division's commercial relations department, has been appointed export sales manager of Dunlop Special Products Ltd.

Mr. L. K. Brindley, M.B.E., has been elected deputy chairman of the Mond Nickel Company and Henry Wiggin & Company. **Mr. G. Archer, C.M.G.,** has been elected managing director of The Mond Nickel Company. **Mr. I. A. Bailey** is moving his headquarters from Birmingham to London where he will continue as a director of The Mond Nickel Company and as managing director of Henry Wiggin & Company. **Dr. L. B. Pfeil, O.B.E., F.R.S.,** has relinquished the managership of the Development and Research Department in order to devote himself more fully to directorship responsibilities. **Mr. R. A. R. Hill** has been elected a director of The Mond Nickel Company and comptroller of The Mond Nickel Company and of Henry Wiggin & Company. **Mr. F. B. Howard-White** has been elected a director of Henry Wiggin & Company and secretary of The Mond Nickel Company and of Henry Wiggin & Company. **Mr. J. O. Hitchcock** has been elected a director of The Mond Nickel Company and appointed sales director. **Mr. F. Dickinson** has been appointed manager of the Development & Research Department. **Mr. A. P. Hague** continues as a director of The Mond Nickel Company and Henry Wiggin and Company and **Dr. A. G. Ramsay** as a director of The Mond Nickel Company, resident in South Wales.

Mr. Leonard M. Broadway, managing director of C. C. Wakefield & Co. Ltd., has been appointed to the Board of the Port of London Authority by the Corporation of London.

Mr. H. Bronniman has been appointed works manager of Lake & Elliott Ltd., Braintree, Essex.

Mr. E. Cattanes, B.Sc., M.Brit.I.R.E., has joined The Solarton Electronic Group Ltd., Thames Ditton, Surrey, as senior commercial executive. He will be responsible for developing the European market for Solarton electronic instruments.

The Right Hon. Viscount Chandos, D.S.O., M.C., has been cleeted President of the British Electrical Development Association, 2 Savoy Hill, London, W.C.2, in succession to Sir John Hackings, M.I.E.E. **The Right Hon. Thomas Johnston, C.H., LL.D., J.P., F.E.I.S.,** chairman of the North of Scotland Electricity Board, and the **Right Hon. Lord Hurcomb, G.C.B., K.B.E., Comp.I.E.E.,** have been elected vice-presidents for 1955/58. **Mr. C. F. King,** chairman of the East Midlands Electricity Board, has been elected chairman of the Council, and **Mr. D. Bellamy, O.B.E., D.L., F.A.C.C.A., F.C.W.A., Comp.I.E.E., F.S.S., F.Econ.S.,** chairman of the Yorkshire Electricity Board, has been elected vice-chairman of the Council.

Mr. John Chaplin, A.M.I.Mech.E., has been appointed to the executive staff of the Chemical Plants Department of Blaw-Knox Ltd., 94 Brompton Road, London, S.W.3.

Mr. K. J. Clarke, A.M.I.E.E., has been appointed assistant manager of the Sheffield district office of British Thomson-Houston Co. Ltd.

Mr. R. T. Collins has been appointed senior project engineer (Midlands), **Mr. G. H. Duffield, Dip.Mech.E., Dip.Chem.E., A.M.I.Mech.E.,** senior project engineer (Northern), and **Mr. M. W. Vincent, B.Sc., A.R.I.C.,** project development engineer, of Sharples Centrifuges Ltd., "Tower House," Woodchester, Stroud, Glos.

Mr. T. A. Crowe, M.Sc., M.I.Mech.E., M.I.N.A., M.I.Loco.E., has been elected chairman and will continue as chief managing director of the North British Locomotive Co. Ltd., Springburn, Glasgow, N.1.

Mr. J. R. Duff, A.M.I.Mech.E., has been appointed works manager of Blackburn (Dumbarton) Ltd.

Mr. R. A. Emerson, chief engineer since 1951, has been appointed vice-president in charge of operation and maintenance of the Canadian Pacific Railway Company, to succeed **Mr. D. S. Thompson,** who has been appointed vice-president with jurisdiction over all its lines.

Mr. S. L. Finch has been appointed joint managing director of Catton & Co. Ltd., Yorkshire Steel Foundries, Leeds 10.

Mr. E. L. Gethin, B.Sc.(Eng.), A.M.I.E.E., has been appointed supplies and production adviser to the British Transport Commission.

Mr. A. Goodsell, Mr. J. H. Orr, and **Mr. G. S. Pound** have been elected to the Board of Coalite and Chemical Products Ltd., Chesterfield.

Mr. Robert L. Green, A.M.I.E.E., has joined Winston Electronics Ltd., Park Road, Hampton Hill, Middlesex, as senior development engineer responsible for telecommunications research and development.

Mr. L. D. Gunnell, general sales manager, and **Mr. H. G. Carter,** secretary, have been elected to the Board of Foster Electrical Supplies Ltd., Morden Road, London, S.W.19.

Sir Patrick Hamilton, Bt., has been elected vice-chairman of The Expanded Metal Co. Ltd., Burwood House, Caxton Street, London, S.W.1.

Mr. W. Hamilton has been appointed sales manager of the Engineering Division of Sheepbridge Equipment Ltd., Chesterfield.

Mr. John Hill has been appointed managing director of Capamianto S.p.A., Turin, the Italian subsidiary of The Cape Asbestos Co. Ltd.

Mr. James Hodge has been appointed London manager of M. & C. Switchgear Ltd., in succession to **Mr. William D. Murray,** who resigned that position, but will continue in a consultative capacity. Mr. Hodge will be in charge of the London office at 36 Victoria Street, S.W.1.

Mr. J. S. Hutchison has been elected chairman of the Board of Metal Industries Ltd., 60 Buckingham Palace Road, London, S.W.1, in succession to **Mr. R. W. McCrone,** who retired from the Board and has been elected honorary president of the company. **Mr. J. O. Knowles,** chairman and joint managing director of Brookhirst Switchgear Ltd., **Mr. J. T. Rymer,** managing director of Sentinel (Shrewsbury) Ltd., and **Sir Charles Westlake** have been elected to the Board of Metal Industries Ltd.

Mr. H. J. D. Kearns, B.A., A.M.I.Mech.E., has been appointed joint managing director, and **Mr. C. A. Sparkes,** chief designer, has been elected a director of H. W. Kearns & Co. Ltd., Broadheath, near Manchester.

Mr. Arthur Keats, O.B.E., chairman and managing director of Fisher & Ludlow Ltd., has been elected to the Board, and **Mr. J. R. Edwards,** a director of Austin Motor Co. Ltd., has been made director of manufacturing, of the British Motor Corporation Ltd., Cowley, Oxford. **Mr. A. J. Burton** and **Mr. J. Tatlow,** local directors of Austin Motor Co. Ltd., have become supervisors of factories of the British Motor Corporation. **Mr. T. G. Bradley,** local director, has been appointed manager of the tractor and

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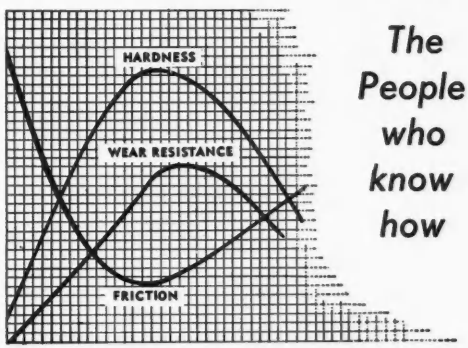

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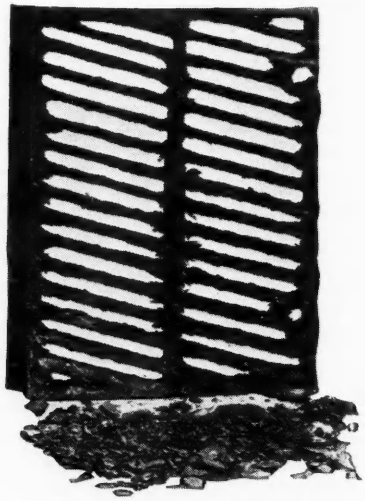

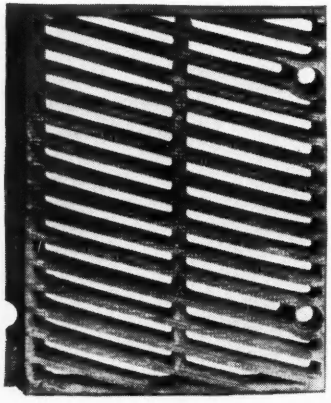

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21/42

transmissions branch, and **Mr. G. W. Rose, O.B.E., T.D. A.M.I.Mech.E.,** has been appointed general manager of the car division of Austin Motor Co. Ltd. **Mr. H. N. Holbeche** has been appointed chief production equipment engineer, and **Mr. F. R. Ford,** chief production planning engineer, of the Midland area factories. **Mr. F. Griffiths** has been appointed production development engineer of the British Motor Corporation. **Mr. G. M. Palmer,** a director of Morris Motors Ltd., has been appointed technical manager, **Mr. W. V. Appleby, A.M.I.Mech.E.,** chief engine designer, and **Mr. H. King** and **Mr. G. Argyle,** joint chief commercial-vehicle designers of the British Motor Corporation Ltd.

Mr. A. N. D. Kerr, A.M.I.E.E., has been appointed district engineer in Bristol, for the counties of Gloucester, Hereford and Somerset, of The Electric Construction Co. Ltd., Wolverhampton.

Brigadier W. S. King, C.B.E., has been appointed by the Minister of Supply, with the agreement of the Secretary of State for War, to succeed **Brigadier F. W. Gordon-Hall, C.B.E.,** as Director of Inspection of Fighting Vehicles with effect from August, 1955. **Brigadier J. L. Morton** will succeed **Brigadier W. S. King** as deputy chief engineer, Fighting Vehicles Research and Development Establishment, Chertsey.

Mr. A. F. Kistner, works director and a member of the Crompton Parkinson Ltd. Junior Board, has been appointed general manager of the Cooke & Ferguson Ltd. Switchgear Works, Manchester, in succession to **Mr. J. R. Ferguson,** who has resigned.

Mr. V. Lehel, A.M.I.Mech.E., has been appointed chief engineer of Alfred Wiseman & Co. Ltd., Glover Street, Birmingham 9.

Mr. F. E. McGinnety has been promoted deputy chief scientific officer and has been appointed by the Ministry of Supply director of the Inspectorate of Electrical and Mechanical Equipment.

Mr. H. Melton has been appointed to take charge of the apparatus and equipment development engineering department of Ericsson Telephones Ltd., Beeston, Nottingham.

Sir Hugh Molony, Bart., M.A., M.A.I., M.I.C.E., who was for a number of years on the engineering staff of the Ministry of Health and until recently with the Ministry of Housing and Local Government, has resigned his official post to take up private consulting practice at 40 King William Street, London, E.C.4.

Mr. K. L. Moon has been appointed sales manager of the Induction Heating Division of Birlec Ltd., Tyburn Road, Erdington, Birmingham 24, a member of the A.E.I. Group. **Mr. A. E. Pickles** continues as manager, and **Mr. R. Abbot,** as technical manager of the Division. **Mr. H. J. Podmore** has been appointed sales manager of the Dryer Division. **Mr. T. C. Sanders** continues as manager, and **Mr. J. W. Carter** as technical manager of the Dryer Division.

Mr. A. E. Morgan, A.M.I.Mech.E., has been appointed works manager of the Atlas Diesel Co. Ltd., Beresford Avenue, Wembley, Middlesex.

Mr. R. D. Pollard has been appointed director and chief metallurgist of Samuel Fox & Co. Ltd., Stocksbridge, Sheffield, in succession to **Mr. G. R. Bolsover,** who is retiring.

Mr. J. C. Poole, A.M.I.E.E., has been appointed deputy engineer-in-chief of the South Eastern Electricity Board, in succession to **Mr. E. H. Skinner,** who has recently been appointed chief commercial officer.

Mr. H. T. Ramsay, M.Sc., M.I.E.E., F.Inst.P., has been appointed director of the Safety in Mines Research Establishment of the Ministry of Fuel and Power, to succeed **Mr. A. H. A. Wynn, M.A.(Cantab.), M.I.Min.E.,** who resigned on his appointment to membership of the National Coal Board.

Mr. A. Scott has been appointed production director of North Eastern Division of the National Coal Board, in succession to **Mr. H. A. Longden,** who has been appointed director-general of production at the Board's headquarters.

Mr. E. V. Small, managing director of the B.T.H. Export Co. Ltd., has been elected to the Board of The British Thomson-Houston Co. Ltd., Rugby. **Mr. D. N. Relf, A.M.I.E.E.,** has been appointed assistant manager, switchgear contracts, at the B.T.H. Willesden Works.

Dr. F. Llewellyn Smith, M.Sc., M.I.Mech.E., managing director of the motor-car division of Rolls-Royce Ltd., Derby, has been elected President of the Society of Motor Manufacturers and Traders, 148 Piccadilly, London, S.W.1, to succeed **Mr. A. B. Waring,** chairman and joint managing director of Joseph Lucas (Industries) Ltd., Birmingham, who now becomes deputy President. **Mr. R. F. Hanks, M.I.Mech.E.,** continues as vice-president for a further year, and **Mr. F. A. Perkins** has been elected a vice-president. **Major-General J. S. Crawford, C.B., C.B.E., M.I.Mech.E., M.I.Mar.E.,** has been re-elected treasurer of the Society.

Mr. D. S. Stewart has joined the Bristol Aeroplane Co. Ltd. as "Brittania" development manager. **Mr. J. H. Holt** has been elected a director of Bristol Aero Engines (Western) Ltd., Vancouver, B.C., Canada.

Mr. N. Tanner has been elected to the Board of Hathernware Ltd., Hathern, near Loughborough, in succession to **Mr. C. E. Taylor,** who has now retired.

Mr. W. T. Towler, of Towler & Son Ltd., Leeds, and **Mr. G. S. Wood,** of Thos. W. Ward Ltd., Sheffield, have been elected to the Governing Council of the British Engineers' Association.

Mr. D. R. S. Turner, B.A., A.M.I.E.E., has been appointed manager of the Larne Works (N. Ireland) of The British Thomson-Houston Co. Ltd. **Mr. S. J. Clarke, T.D., Assoc.I.E.E.,** has been appointed manager of the Manchester district office, and **Mr. F. C. Barford, T.D., M.I.E.E.,** manager of the Birmingham district office.

Mr. Robert Q. Wilson has been appointed United Kingdom representative in charge of Batelle Memorial Institute's recently established office, Batelle Institute Ltd., 46 Bryanston Street, London, W.1. He will maintain liaison for British firms sponsoring research at Batelle laboratories in Columbus, Ohio, Geneva and Frankfurt/Main.

METROPOLITAN-VICKERS ELECTRONICS DEPARTMENT

A new Electronics Department formed at Metropolitan-Vickers Electrical Co. Ltd., Trafford Park, Manchester, incorporates the Radio Department, part of Marine and Special Contracts Department, and the service electronics section of Industrial Electronic Control Engineering Department, the industrial section of which has been re-named Industrial Process Control Engineering Department.

Mr. E. T. W. Barnes has been appointed superintendent, Mr. D. E. Thornhill, B.Sc.Tech., Grad.I.E.E., assistant superintendent, Dr. L. W. Brown, chief engineer, Mr. J. L. Russell, A.M.I.E.E., assistant chief engineer (Special Applications), Mr. L. H. J. Phillips, sales manager, and Mr. J. Nicholson, assistant sales manager.

Mr. G. W. G. Canter has been appointed manager, Special Contracts, and will be located in London.

ENGLISH ELECTRIC ATOMIC POWER DEPARTMENT

The English Electric Company Ltd. announces the establishment of a special department to deal with atomic power station development, thus playing its part in implementing the policy of expansion of nuclear power resources for peaceful purposes laid down in a recent Government White Paper.

The Prime Minister referred to progress with this policy last Saturday at a meeting in London when he said: "Already many companies in this country are exploring markets overseas for their new products in this field. We hope to produce an entirely new export trade. The scope is enormous. Throughout the Commonwealth and Empire wide areas are hungry for power. Nuclear energy may be the way of raising living standards in these areas."

In the development of atomic power plant, English Electric will work in conjunction with Babcock and Wilcox Ltd., who have played an important part in the design and construction of Calder Hall, the world's first full-scale atomic power station, which is situated in Cumberland. English Electric have also supplied electrical equipment to the Calder Hall installation.

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The headquarters of the company's atomic power work is at Whetstone, near Leicester, where the administrative, design, experimental and drawing office staffs are already established. English Electric acquired the Whetstone premises of the National Gas Turbine Establishment last January.

Mr. P. H. W. Wolff has been appointed chief engineer of the atomic power department at Whetstone. Previously he was engaged on gas turbine development work for The English Electric Company at Rugby.

This announcement indicates that an important section of English Electric's engineering activity, including that relating to all prime movers, atomic power and the new mechanical engineering laboratory, is now centred round Rugby. The main works are at Rugby, and the mechanical engineering laboratory is at Whetstone.

Considerable expansion of technical staff and facilities is now taking place in the Rugby area, both for established products and new lines. Dr. H. S. Arms is now the chief engineer, English Electric, Rugby, and is responsible for the overall technical policies to be followed by all departments at Rugby and Whetstone.

THE NUCLEAR POWER PLANT CO. LTD.

A group of firms who either have had close association with the United Kingdom Atomic Energy Authority in the design and construction of the Calder Hall Atomic Power Station, or in experimental reactors for Harwell, or who have special experience and facilities for such work, are associated with a recently incorporated separate company which will concentrate on the research, design and construction of nuclear power stations.

Registered with an authorized capital of one million pounds, The Nuclear Power Plant Co. Ltd. has its registered office at Heaton Works, Newcastle upon Tyne. The design headquarters is Booths Hall, Knutsford, Cheshire.

The associated Companies are C. A. Parsons & Co. Ltd., A. Reyrolle & Co. Ltd., Head, Wrightson & Co. Ltd., Sir Robert McAlpine & Sons Ltd., Whessoe Limited, Strachan & Henshaw Ltd., Alex. Findlay & Co. Ltd., and Clarke, Chapman & Co. Ltd.

The directors of N.P.P.C. are Sir Claude Gibb, C.B.E., D.Sc., F.R.S., President and Chairman, Dr. A. T. Bowden, Ph.D., M.I.Mech.E., R. Edwin McAlpine, Richard Miles, B.Sc., M.I.Mech.E., Harold H. Mullens, B.Sc., M.I.E.E., Arthur J. Sayers, A.M.I.E.E., and Sir John Wrightson, Bt., T.D.

D. P. Walton, A.C.A., is the secretary.

The Parolle Electrical Plant Co. Ltd. (joint proprietors—Parsons Reyrolle), who have been associated with the Atomic Energy Authority in the design and construction of the Calder Hall Power Project, will co-ordinate the activities of the eight co-operating companies in design and construction. They also will be responsible for site services.

NATIONAL COAL BOARD

In accordance with a recommendation of the Advisory Committee on the National Coal Board's organization (the Committee was presided over by Dr. A. Fleck, Chairman of I.C.I.), a Purchasing and Stores Department has been established at National Headquarters, and at Divisions and Areas will operate from July 1st. A Director-General will be appointed and there will be Divisional Purchasing and Stores Controllers and Area Purchasing and Stores Managers. The Board Member responsible for the Department is Mr. R. H. E. Thomas, O.B.E.

THE FILE RESEARCH COUNCIL

Arrangements for the formation of a co-operative Research Organization for the File making industry have been completed.

A research team will be built up and housed in laboratories rented from the British Iron & Steel Research Association in Sheffield. The File Research Council will finance, control and operate their own specialist research facilities, but file research staff will be able to draw on B.I.S.R.A. information and metallurgical data. This arrangement has become possible through the co-operation of B.I.S.R.A. Council and its Director, Sir Charles Goodeve, F.R.S.

The 39 firms supporting the File Research Council are confident that by pooling their resources in this way and receiving the additional assistance of B.I.S.R.A. and D.S.I.R. they will be able greatly to strengthen their position and benefit all engaged in the industry.

Preparatory work has already commenced with the formation of Executive and Research Committees under the chairmanship of Mr. R. P. Wallace of Wm. Jessop & Sons Ltd., and Colonel W. S. Tyzack of W. Tyzack, Sons & Turner Ltd. respectively. The Council's research superintendent will be Mr. C. N. Kington, Group Manager of B.I.S.R.A. (Sheffield) Laboratories, who will also retain his position as research superintendent of the Cutlery Research Council. The secretary of the File Research Council will be Mr. E. A. Tuxford, Light Trades House, Melbourne Avenue, Sheffield, 10.

BUSINESS NOTES

Residential Course on "The Fatigue of Metals." A week's residential course on the fatigue of metals is being held at the University of Nottingham from September 12th to 16th, organized by a joint committee of industry and the engineering departments of the University under the chairmanship of Mr. G. Forrest. As this University carries out a considerable amount of research in the fatigue of metals it is quite natural that such a course should be centred on Nottingham.

It is intended that the course should present the known facts concerning the fatigue of metals to the practising engineer, and, although no formal academic qualifications are required for enrolment, it will be assumed that those attending the course will possess either a degree or the Higher National Certificate in engineering or science. The subjects to be covered are :—

The fundamentals of fatigue.
The fatigue properties of steels and cast iron.
The fatigue properties of non-ferrous alloys.
Corrosion fatigue and fretting corrosion.
Fatigue of aircraft.
Fatigue testing.

Residential accommodation for 100 people will be provided in Hugh Stewart Hall, which is situated in the University Park.

All inquiries regarding the course should be addressed to the Secretary, Fatigue of Metals Course, Departments of Civil and Mechanical Engineering, University of Nottingham, University Park, Nottingham.

English Steel Corporation Ltd. announce the formation of a new wholly-owned subsidiary company under the name of Davis & Lloyd (1955) Ltd., which has taken over the interests of Davis & Lloyd Ltd., of 26 Victoria Street, London, S.W.1, in the design and production of cast steel Side Frames and Bolsters, cast steel Unit Brake Beams, Snubbers and other parts and appliances for railway rolling stock.

Mr. Ernest Lloyd, chairman and managing director of Davis & Lloyd Ltd., has retired but will be available in a consultative capacity. Mr. F. Mason, a director, becomes a director of the new company.

Mr. F. Pickworth, managing director of English Steel Corporation Ltd., and Dr. C. J. Dadswell, a director of English Steel Corporation Ltd., become chairman and managing director respectively of Davis & Lloyd (1955) Ltd., with Mr. F. S. Beale, a director of English Steel Corporation Ltd., also a director of the new company.

The A.P.V. Company Ltd. have formed a new company, A.P.V. (Canada) Equipment Limited, to take over Walker-Wallace Ltd., Toronto, who have been their Canadian agents since 1929.

Mr. K. L. Wallace will continue as President of the new company with Mr. H. J. A. Painter, Vice-President.

Winston Electronics Ltd. have moved to new factory premises at Govett Avenue, Shepperton, Middlesex. Tel. No. : Walton-on-Thames 2732.

Edgar Allen & Co. Limited have acquired the business of makers of electro-magnetic chucks and demagnetizers carried on by Messrs. J. H. Humphreys & Sons, Oldham. A new company, J. H. Humphreys & Sons Limited, with an authorized capital of £100,000, has acquired from the original firm the Blackriding Electrical Works, Werneth, Oldham, from which address the business will be carried on without interruption.

Mr. Albert Humphreys has joined the Board of the new Company, and he and Mr. Augustus Humphreys, both partners in the original firm, have agreed to serve the Company for the time being.

ADOPTION OF THE UNIFIED SCREW THREAD BY BRITISH INDUSTRY

The conclusion that the Unified Screw Thread would ultimately supersede the Whitworth Thread was formally recorded by a special conference at British Standards House on 23rd May, when representatives of many branches of the engineering industries, the Service Departments, and the nationalized industries met under the chairmanship of Mr. H. A. R. Binney, director of the B.S.I.

The conference was called in response to many inquiries which B.S.I. had received from industrial producers and users of engineering equipment, from Government departments and others concerned to know how far and how fast the change-over from the Whitworth Thread had progressed in the seven years since the signing of the "Declaration of Accord" between America, Britain and Canada, under which the three countries agreed to accept the Unified Thread.

It was recalled in the opening discussion at the conference that in the years immediately following the signing of the Accord several British Standards were developed for Unified bolts and nuts, screwing tackle and other details necessary for the implementation of the agreement. Reviewing progress from that point, the manufacturers of bolts and nuts said that in the early stages they had been unable to meet all the demands for Unified bolts and nuts, but recently the position had improved. The draft standard for black bolts and nuts in the "normal" series would soon be issued, and they now foresaw no serious difficulty in meeting any future demands likely to be made upon them.

Representatives from the motor, aircraft, oil and chemical industries and from the Atomic Energy Authority all said that they had adopted the Unified Screw Thread, and confirmed that by and large availability now presented no problem. They were unanimous in stating that the change-over had not been nearly as inconvenient as they had thought it would be, and they were of the opinion that the difficulties involved could easily be exaggerated.

The discussion brought out that one of the major difficulties to be faced related not so much to the change from Whitworth to Unified bolts and nuts, but to the fact that tapped holes were employed in such a great variety of engineering equipment produced in a wide range of separate industries which included many comparatively small firms.

The conference felt that the three key factors in the further progress of the change-over were :—

(a) **large organizations such as the nationalized industries** which placed many large orders for equipment, and which, by specifying Unified Screw Threads, could help to influence and speed the change-over ;

(b) **the stockist,** who was responsible for supplying small orders to a great number of small firms ; and

(c) **the many small manufacturers,** who produce miscellaneous industrial equipment with tapped holes.

The indications all showed that the rate of the change-over had been considerably faster than might have been expected some four or five years ago ; but, having regard to the advantages to be achieved by working to a single screw-thread system, particularly one which there is every reason to believe will receive increasing support in the Commonwealth and other overseas markets, it was generally agreed to be desirable that the tempo of the change-over should be increased.

CONTRACTS

Head Wrightson Processes Limited announce that in conjunction with the Fluor Corporation Limited they have received the order for two Gas Dehydration Plants to dehydrate 18,000,000 cubic feet of gas each daily for the Gas and Fuel Corporation of Australia. Located at Morwell, the plants will process gas extracted from the brown coal deposits nearby, and supplies will be piped to the city of Melbourne.

The Material Handling Division of Fisher and Ludlow Ltd., Birmingham, have received a contract from the U.S. Army Air Force in France. This contract, which is of very considerable dollar value, covers the supply of half a million lineal feet of "Flowstrut" Slotted Angle and one hundred and twenty thousand square feet of "Flowforge" Open Steel Flooring, the only electrically forge-welded flooring manufactured in Europe. These two products and ancillary equipment combine to form storage platforms of a unique design and almost double the storage capacity of existing buildings. As could be expected, competition for a contract of this nature was particularly keen, from both British and Continental sources.

The General Electric Co. Ltd. has received an order from the British Transport Commission for the complete traction equipment of 57 new three-coach multiple-unit train sets to replace existing rolling stock on the Euston-Watford service, London Midland Region. Each three-coach set will consist of a motor-coach, trailer and driving trailer. The rolling stock, to be built in British Railways workshops, will be of the compartment type with central corridor. This will be the first order for which the G.E.C. will manufacture all the traction motors and auxiliary machines in its new factory at Dudley Port, acquired recently to meet the growing demand for electric and diesel-electric traction equipment. The value of the order is approximately £741,000.

Foster Wheeler Limited has been awarded a contract by the Iraq Government for the design, supply and construction of a complete lubricating oil refinery in Iraq to produce 25,000 metric tons a year of high-grade lubricants.

The units include Vacuum distillation with fired heater and steam condenser ; Propane dewaxing ; Propane deasphalting with propane preparation plant ; Furfural refining ; Acid treating ; Clay percolation ; Cooling tower ; Drum and can making plant with filling facilities ; Water treatment ; Tankage ; Off-site facilities.

The General Electric Co. Ltd. has been entrusted by the Central Electricity Authority with a contract valued at £364,000 for a 132kV outdoor substation which will form part of the new base-load generating station now under construction at Willington, near Derby, in the East Midlands Division. The substation will control six feeders linking Willington with Spondon, Allenton, Winster and Drakelow on the existing 132kV grid system, and two feeders linking the new station with the 275kV Supergrid.

A layout providing duplicate busbars arranged in a U-shaped formation has been adopted for the substation, which will consist of 14 bays each equipped with an oil circuit breaker rated at 3500 MVA at 132kV. The contract includes all the overhead conductors, isolators and surge diverters in addition to the protective equipment, control panels and auxiliary gear.

International Furnace Equipment Company Limited, Aldrich, Staffordshire, have received a further order for a GI two-stage gas generator for the production of clean gas from the English Steel Corporation Limited, Sheffield. This is the third plant of this type to be installed at the River Don Works of the English Steel Corporation, two others having been installed about a year and a half ago.

Classified Advertisements.

The rate for all classified advertisements is 6d. per word ; in bold print 9d. per word ; minimum order 6s. Box-number advertisements 1s. extra. Instructions, together with remittance, must be received not later than the 3rd of each month for advertisements to appear in the same month's issue.

SITUATIONS VACANT

PRODUCT ENGINEERS having experience in thermostatic controls, thermal and starting relays are urgently required by progressive light electrical engineering firm in Glasgow area. Applicants should be of H.N.C. standard. Conditions include 5-day week, Pension and Life Assurance scheme. Assistance will be given to suitable applicants requiring housing accommodation. Apply in writing giving details of experience, age and salary required to Box No. 36.

DESIGNER ENGINEER is offered a position in West London Engineering Works covering an unusually wide range of machine design. The Company manufactures special-purpose machines for leading Companies in many industries. The work involved offers a very wide scope to an experienced machine designer. Salary offered would be commensurate with experience. Apply giving full details of training, experience and qualifications to Box No. 37.

FERRANTI LIMITED, EDINBURGH
Engineers

Applications are invited for positions in our Production organisation which is engaged in the manufacture of precision electromechanical/electronic equipment. Applicants should hold a degree or diploma in Electrical Engineering, Mechanical Engineering or equivalent, but consideration will be given to applicants holding a H.N.C. in Engineering and who have completed an engineering apprenticeship. The vacancies are for :—

(A) **ENGINEERS** to work on the application of computer-controlled machine tools with reference to the utilisation of these in a production organisation, investigation into the material handling, setting, jigging and fixing methods to be employed with such machines :

(B) **PROJECT ENGINEERS** to take charge of the complete manufacture of complex electromechanical/electronic equipment—experience in production operations is essential in this case :

(C) **TECHNICAL PROJECT ENGINEERS** who do not possess the necessary practical experience for (B) but have a flair for production matters and who would act as technical assistants to the Project Engineers in the first instance with a view to promotion to Project Engineers in due course.

Salary according to age, qualifications and experience. Staff Pension Scheme. Ideal working conditions in modern factory furnished with the most modern equipment. Please address full details of technical qualifications, age and experience, and stating post applied for to the Personnel Officer, Ferranti Limited, Ferry Road, Edinburgh, quoting Ref. 71/F.E.

A medium-size Foundry and Engineering Works in Bedfordshire requires a **MAINTENANCE INSPECTING ENGINEER** for plant and machinery, also to function as Safety Officer. Qualifications : Higher National Certificate, together with full mechanical or electrical engineering apprenticeship. Drawing office experience an advantage. Pension Scheme, Social and Welfare facilities. Apply in own handwriting, giving age (limits 25-38), training, experience, qualifications, copies of testimonials and salary required. Box No. 38.

BEARINGS

BALL & ROLLER BEARINGS.—All Types and Sizes, Largest Stocks, Lowest Prices. Same day dispatch. **895-921 Fulham Rd., London, S.W.6.** Renown 6174 (Ext. 24).

A PROGRAMME OF NUCLEAR POWER

THE UNITED KINGDOM ATOMIC ENERGY AUTHORITY

(Industrial Group)

has a large part to play in this Programme, both in the production of fissile material and the design and construction of prototype nuclear power reactors. This will involve an increase in the scale of activity of the Research and Development Branch, which is responsible for the applied research and development work required for the design and operation of new chemical plant and of prototype nuclear reactors.

There are vacancies in the Research & Development Branch for ***Chemists, Chemical Engineers, Metallurgists, Physicists, and Engineers*** at salaries up to **£1,620** per annum with prospects for further advancement at the laboratories mentioned below. The laboratories are well-equipped for the most modern techniques of research and development and for carrying out full scale tests. The fields of work covered by these laboratories are briefly :—

WINDSCALE (Cumberland)
Research and Development work concerned with the design and operation of nuclear reactors and industrial chemical processes for radio-active materials. The work involves general and nuclear physics, heat transfer and fluid dynamics, chemical engineering and the chemistry and metallurgy of radio-active materials and irradiated metal.

DOUNREAY (Caithness)
This laboratory will be set up in the near future on the site of a reactor of very advanced type and the staff will have to deal with novel problems in general and nuclear physics, engineering, chemical processing and metallurgy. Pending completion of the laboratory, they will be expected to serve in an appropriate section of one of the other Research and Development Laboratories.

SPRINGFIELDS (West Lancs.)
Laboratory and pilot scale work on the extraction of unusual metals from their ores, the preparation of pure metals and compounds and their fabrication into components for nuclear reactors. The work involves physical and inorganic chemistry, chemical engineering, reduction of metals, powder metallurgy, casting, mechanical work, physical metallurgy, instrumentation, vacuum techniques, non-destructive testing and general physics.

CAPENHURST (Cheshire)
Development work in connection with the design of prototype nuclear reactors, diffusion plants and novel processes. The work involves applied physics, fluid dynamics, applied kinetic theory, mechanical engineering, heat transfer, liquid metals technology, fluorine chemistry and advanced instrumentation.

CULCHETH (South Lancashire)
Study of materials of construction and their properties with respect to nuclear reactors and associated chemical plant. The work involves, on the laboratory scale, extraction chemistry of rare and unusual metals, refractories, physical metallurgy, deformation of metals, general physics, the melting and fabrication of metals, powder metallurgy and corrosion.

RISLEY (South Lancashire)
This group acts in an advisory capacity to the Laboratories and to the Design and Operations Branches on physical, chemical, engineering and metallurgical problems. Theoretical studies on advanced physical, mathematical and engineering problems are carried out, and process evaluations and chemical flowsheets prepared. There is a small section dealing with the planning and technical administration of the Research and Development Branch, and a Library and Information Service.

All posts are permanent and pensionable. Houses will be available in many cases within a reasonable time.

Send postcard for further particulars including details of minimum qualification requirements to :—

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RISLEY · WARRINGTON · LANCS

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B

Stoneware in EJECTORS means CORROSION IMMUNITY

HATHERNWARE EJECTORS are made of high-grade Hathernware Chemical Stoneware, with steel or iron armouring as required. The adoption of Chemical Stoneware for these instruments adds greatly to their usefulness in the Chemical and allied trades, as Hathernware is proof against the attack of practically all industrial acids and corrosive liquors at all concentrations and temperatures.

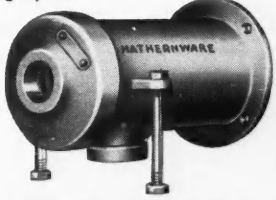
TYPICAL APPLICATIONS :

- Maintaining vacuum on filters and other closed vessels.
- Entraining, discharging and absorbing gases.
- Priming pumps and setting syphons.
- Lifting liquids.
- Heating and circulating liquids.

Illustrations :

(Top Armoured Stoneware Swirl-type Ejector (water operated).

(Bottom) Standard Iron-armoured Ejector.



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BOOKS RECEIVED

Fishing Boats of the World. Edited by Jan-Olof Traung. 650 pp., 604 illustrations. Published by "Fishing News," Arthur J. Heighway Publications Ltd., Ludgate House, 107 Fleet Street, London, E.C.4. Price: 90/- (or $12.50).

The fishing boats of the world, of all types, shapes, and sizes, represent the largest single collective investment in the world's fishing industry. Upon their efficiency of design and operation depend the economy of many people and the lives of the fishermen who man them. This book, which has been published in co-operation with the Food and Agriculture Organization of the United Nations (FAO), Rome, contains the experience of specialists from most parts of the world in which fishing is carried out, and is a symposium of present knowledge of fishing-boat design and construction.

The material in this interesting book is based on a collection of papers presented at the FAO International Fishing-Boat Congress held in Paris and Miami in 1953. About 140 contributors are represented; of these, 70 presented papers, while the remainder took part in the discussions, which also figure in the book and which themselves form a lively, controversial, and informative contribution.

The book is profusely illustrated with photographs of fishing vessels under construction and in operation, and with plans and detail drawings. It should, however, be understood that it is not, nor is it intended to be, a textbook on naval architecture. On the contrary, it deals with that part of fishing-boat design which is missing from textbooks on naval architecture, and provides, in compact form, a wealth of valuable and practical information for all those connected with the fishing-boat building industry.

The Testing of High-Speed Internal Combustion Engines. 4th edition, 1955. By Arthur W. Judge. 510 pp., 398 illustrations. Publishers: Chapman & Hall, Limited, 37 Essex Street, London, W.C.2. Price: 75/-.

With the ever-expanding use of high-speed internal combustion engines, there have been in recent years notable developments in engine-testing methods and equipment to ensure greater accuracy of measurement, with more simplified controls for the test engineer.

In the fourth edition of this well known book, much new information and data have been included with regard to methods and instruments concerned with measurements of fuel quantity and rate, exhaust-gas composition, diesel-engine smoke density, static and variable cylinder pressure, and temperatures, air consumption, speed, and certain other quantities involved in engine testing and test analysis.

In particular, the section dealing with methods of measurement of brake horse power has been rewritten and expanded, to include accounts of the most recent types of brakes and dynamometers, with special regard to the electric and power recuperation units; in this connection, the modern eddy-current and dynamatic models receive special consideration. Furthermore, the various standard test formulae employed to take account of atmospheric-pressure, temperature, and humidity variations have been included and a useful standard test chart has been provided, for simplifying the reduction of tests to standard results. Information concerning the more recent fuel knock-rating tests has also been given.

In view of the important developments in aircraft gas-turbine design and production, an entirely new section devoted to the subject of testing this type of gas turbine has been added; also, the previously published account of aircraft piston-engine testing has been revised and brought up to date.

LATEST INDUSTRIAL LITERATURE

1. Arc Furnaces. In a superbly produced 30-page publication with many illustrations in colour, details are given of a range of arc furnaces, including top-charging furnaces and furnaces for ferro-alloys, calcium carbide, and abrasives.

Advantages of these furnaces include the fact that three distinct types are available, to cover all sizes and operating conditions; furthermore, their high electrode speeds ensure rapid breaking down of the melt, their rise and fall speeds are independently controlled by adjustment of a valve, and their robust and precision construction ensures long life and low maintenance costs.

2. Band Sawing and Filing Machine. An illustrated 4-page brochure describes an interesting new band sawing and filing machine which, although of small size, has many big possibilities in sawing and filing work, both in large and small shops.

The machine can quickly be converted from sawing to filing by replacing the saw with a filing band consisting of 26 files and one special recessed jointing file carried on an endless steel band. These bands are available in three widths, i.e., ¼ in., ⅜ in., and ½ in., and can be supplied in two shapes, i.e., flat and contour.

A brazer, flush-mounted in the front of the machine, and suitable for saws up to ⅜ in. in width, is fitted as standard.

3. Airport Electrification. In a well-produced and excellently illustrated 48-page publication, details and diagrams are given of airport lighting systems, the various control systems used for this aspect of airport operation, telecommunications, and equipment peculiar to airports. A two-runway airport, similar in size and layout to those in common use throughout the world, has been taken as a basis for the illustration of various proposals, though naturally such proposals can be adapted to any other layout.

The recommendations made are the result of extensive experience in studying the problems associated with the handling of aircraft, passengers, and freight, both when airborne and when on the ground.

4. Automatic Drill Head. Details are contained in a well-produced 12-page illustrated brochure of an efficient and compact drilling unit with completely automatic built-in controls. No shop air lines are required, and the machine is self-compensating for both drill size and material hardness. This drill head employs "resistance drilling," which takes into consideration the inherent weakness of small drills and permits drilling at the maximum twist-drill strength, utilizing the material as a speed and feed regulator.

The unit, which is only 14½ in. in length by 4½ in. in diameter and weighs 17½ lb, is powered by a specially engineered motor, while the drill head has a Jacobs chuck mounted on one end of the armature shaft and a rotary compressor at the other. The motor performs a dual role in that it not only furnishes its own drilling power but also generates its own air supply to advance the drill into the work-piece. As a result, the unit is simple, versatile, portable, highly productive, and easy to set up and to operate.

5. Balanced-Grip Soldering Gun. A pamphlet describes and illustrates a balanced-grip soldering gun in an unbreakable case, with many interesting features. The balanced grip and trigger control make it specially suitable for easy soldering on hard-to-reach jobs, while the exclusive alloy tip never requires retinning and should last indefinitely with normal use and care. The gun is of "pocket" size and weighs only 24 oz.

The device works on a different principle from that of the ordinary soldering gun, inasmuch as a current of high amperage produced in a transformer serves to heat the soldering tip within six seconds. For service calls and small bench jobs, this gun should prove of inestimable value.

6. Photocopying and Projection Equipment. Details are presented in a 12-page illustrated booklet of a range of photocopying equipment suitable for the rapid reproduction or adaptation of documents, drawings, photographs, and even small groups of three-dimensional objects. All copying equipment uses the vacuum method, which is fool-proof and which guarantees perfect contact over the whole surface to be copied. Hence, books, ledgers, etc., can be dealt with as readily as single sheets.

The projection equipment enables natural-colour images of artwork, layouts, and even simple three-dimensional objects to be thrown on a flat 22-in. screen, set at a convenient height for viewing. Special lenses are fitted, permitting the picture to be enlarged up to seven times, or reduced to one-seventh, the original size.

7. Balancing Machines. Photographs and brief descriptions of a comprehensive range of balancing machines, manufactured by a firm with nearly 40 years of experience in the design and construction of such equipment, are given in a 4-page brochure.

The range includes dynamic rapid balancing machines, with electric indication; special dynamic machines, with stroboscopic indication for direction and electric indication for the amount; measuring equipment for investigation of vibrations on moving motor-cycles; dynamic light-ray high-production machines for balancing motor-car tyres and rims and for wheel-shaped rotors in one plane; small precision dynamic machines for small electric armatures; and dynamic balancing machines and balancing scales for repair shops.

8. Vortex-Flame Oil Burner. A 4-page brochure describes and illustrates a fully automatic and self-igniting vortex-flame oil burner with many outstanding features. In this design, the oil spray is efficiently atomized by a swirling vortex of air to form a bowl-shaped luminous flame which transmits radiant heat directly to the heating surface of the boiler itself, more positively and efficiently than the solid-fuel fire for which boilers are generally designed.

No complicated or awkwardly shaped refractory brickwork is necessary inside the boiler combustion chamber; as a result, the whole of the side walls and crown, as originally included in the boiler design, are exposed to radiant and convected heat. Furthermore, the burner has no moving parts, eliminating heat damage from the burner and frequent adjustment and service.

9. Flexible Couplings. Details are contained in an illustrated pamphlet of a range of flexible couplings designed to provide smooth power transmission with a consequent reduction in torsional vibration. Other advantages of these couplings include maximum absorption of torsional shock; compensation for possible misalignment, axial displacement, and parallel displacement; minimum size and weight; maximum endurance; and safe operation.

Individual metal parts are of unit construction and a single rubber element is used. Dangerous projections have been eliminated, so that rotating parts present a smooth external surface. Furthermore, these couplings are easily fitted and dismantled.

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120, Wigmore Street, London, W.1.

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THE BLUE PAGES

A QUICK GLANCE AT THE LATEST TECHNICAL DEVELOPMENTS THROUGHOUT THE WORLD

● *COATING METAL PARTS WITH NYLON*

A relatively inexpensive method of applying thin, strongly adherent coatings of nylon to metal surfaces has been developed, making it possible to take advantage of the favourable friction and wear characteristics of this material. In a typical experiment, two uncoated metal surfaces of a flat-plate air valve, rubbing together with good lubrication, withstood 100,000 actuations before the valve failed from wear. A coating of nylon, 0·005 in. in thickness, was applied to one face of a similar valve and then ground down to 0·003 in. It was found that, with one surface nylon-coated, the valve withstood more than ten times as many actuations, no lubrication at all being applied. Adherent coatings of nylon, from 0·002 to 0·003 in. in thickness, have been applied to many types of steel, including stainless steel, and also to aluminium. Ceramics have also been coated successfully. Coatings on copper and copper alloys are said not to have met with any success so far. Nylon coatings can be applied to metal in several ways. In the most promising method, the metal part is preheated to a certain temperature above the melting point of nylon and then dipped into nylon which is in a specially prepared solid form. The result is claimed to be a homogeneous, solvent-free coating which needs no after-bake or other hardening treatment. Correct preparation of the metal surface is said to be an important factor, but no information in this respect has as yet been divulged. The possibility of coating metal gears with nylon, in order to circumvent the tolerance problem encountered in the manufacture of solid nylon gears, is being considered.

● *LUBRICANTS FOR TITANIUM SURFACES*

Clean titanium surfaces subjected to rubbing are known to show high friction and wear. This is due to the fact that titanium easily forms strong welds with other metals, and that comparatively large amounts of titanium are transferred to the other surface. Commercial liquid lubricants which are easily adsorbed on the surface of other metals are not effective in the case of titanium rubbing on titanium; solid lubricants, on the other hand, are ineffective because they are weakly bonded to the metal and are therefore easily pushed aside. A recent report summarizes attempts made to exclude or alleviate the welding and galling characteristics of titanium. When trying mineral oils as lubricants, it was found that the reduction in the coefficient of friction was so low as to make them useless. Long-chain hydrocarbon derivatives produced the same negative result. Since the poor lubrication of titanium can be ascribed to unusual properties of its surface layers, it was thought that a chemically active liquid might dissolve, or otherwise modify, the surface layers and thus allow better lubrication. The coefficient of friction was lowered slightly, but the rate of reaction of the liquid with the titanium surface was slow and the nature of the liquids was considered unsuitable for general use. Tests with synthetic long-chain compounds such as silicone oils, polyethylene glycols, and polypropylene glycols revealed a certain reduction in friction. Halogenated hydrocarbons provided good lubrication, polychloro-trifluoroethylenes being especially effective. Long-chain hydrocarbons with halogen groups on only one or a few carbon atoms gave high friction coefficients, and it appears that effective lubricants should have every, or every other, carbon atom halogenated.

● *CAST-IRON BOLTS FOR PIPE JOINTS*

A novel metallurgical process has been devised to produce cast-iron bolts for mechanical joints in cast-iron pipe. In this process, white-iron bolts are cast continuously in metal moulds mounted on turntables and malleablized by annealing. The unique feature of the process is that, because of quick freezing in the metal moulds, the silicon content of the iron can run as high as 3%. This material can be annealed in approximately one-tenth of the time required for conventional sand-cast materials. It is claimed that the annealed bolts have good machinability for threading, combined with a tensile strength of some 60,000 psi and adequate toughness. The corrosion resistance of this iron is said to be at least comparable with that of the cast-iron pipe. The desirable analysis for the material is given as 2·4 to 2·8% total carbon, 2·6 to 3·2% silicon, 0·15% sulphur max., 0·15% phosphorus max., and 0·6 to 1·0% copper. When the metal is poured into the cast mould, a completely white-fracture casting is obtained. Malleablizing heat treatment is carried out at 1700° F for 45 minutes. The bolts are subsequently cooled in about 1½hr to 1250° F in the furnace and then finally cooled in air. The microstructure of the annealed bolt metal con-

Meet Perishin' Fred!

Very fond of a grouse is Fred. Doesn't have to look far either. 'Like the perishin' North Pole in this perishin' factory', growls Fred. But at least he stays on the job; half the girls are away with the sniffles.

Now meet Bert — of the boiler'ouse

'It's no good them coming grousing to me,' glowers Bert, 'radiators are full on (or nearly), and the Guvnor's always bitin' my 'ead off about the fuel bills.'

You know the answer to all their troubles as well as we do. Inter-line that corrugated roof with inexpensive, easily-applied, everlasting Fibreglass heat insulation. Then Fred will stop perishin', Bert will stop beefing and the 'Guvnor' will stop biting. What's more, the installation of Fibreglass *will pay for itself* in less than three years!

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sists essentially of temper carbon nodules in a matrix of silicoferrite. The effect of nearly 3% silicon and 1% copper in solid solution in the ferrite is to increase hardness and strength considerably above those of ordinary malleable iron, although ductility is lowered. Care must therefore be taken not to overload the bolt by excessive tightening.

● *DETERMINATION OF STRESS CONCENTRATION*

A recent research report describes the experimental determination of stress concentration in a shaft with transverse holes subjected to torsion. The investigators point out that usual methods of stress measurement, such as brittle coatings and the use of sensitive extensometers, could not be applied effectively because the maximum stress occurs in the bore and not in the outer surface of the shaft. It would be possible to measure the stress by the stress-freezing and slicing method, but in the case where the diameter of the hole is comparatively small, this method suffers from lack of accuracy. It was therefore decided to employ the electroplating method instead. This method is based upon the phenomenon that, when a specimen plated with copper containing some impurities is subjected to stress reversals of suitable magnitude, the surface of the specimen changes in colour, owing to the flecks produced by fatigue. The variation in the appearance of flecks, due to the change of load, is very pronounced at the proper loading conditions, so that an accurate determination of the surface stress is feasible by observing the flecks produced. The value of the cyclic load below which these flecks do not appear is characteristic of the plating metal, the impurities contained in the plating metal, and the impurities contained in the plating solution, if the specimens are plated under the same conditions. Having determined the locations of stress concentration, the investigators carried out further tests to obtain stress-concentration factors for shafts with transverse holes of various diameters. It was found that, in a certain range of small hole-diameter/shaft-diameter ratios, stress concentration actually decreases with increased hole diameters.

● *EVAPORATED MAGNETIC MATERIALS*

In endeavouring to obtain improved magnetic material through change in form, an examination was recently made of the possibilities of producing useful magnetic materials by means of a vacuum evaporation process. This approach was made with three distinct possibilities in mind, i.e., nearly complete elimination of eddy-current losses; improved control over hysteresis loop form; and the inherent economy associated with a vacuum-coating technique as a production method. The preparation of the evaporated materials was conducted in a vacuum chamber, from which the air was exhausted to a pressure of approximately 10^{-4}mm Hg to reduce the possibilities of contamination by gas and to increase the mean free path of the metallic atoms. The substrate, which may be a highly glazed ceramic or glass form or a sheet of plastic material, is mounted above a crucible containing the magnetic material. When residual pressure has been reduced to an operating vacuum, the metal-filled crucible is heated by high-frequency induction. The metal then melts and evaporates. Under these conditions, the metal atoms leave the surface singly and travel for the most part along straight, undeflected trajectories until they strike the substrate or the walls of the chamber. To build up a reasonable volume of magnetic material and still keep eddy-current losses within practical limits, multi-layered films must be deposited with a layer of insulation between the metallic layers. This can also best be effected by evaporation, which is carried out by placing a second crucible containing a dielectric material in the chamber. It is reported that, up to the present, some of the best results have been obtained with permalloys having compositions in the neighbourhood of 80% nickel and 20% iron, and using magnesium fluoride as the evaporated dielectric.

● *EPOXY RESINS AS MOUNTING MATERIALS*

The accurate mounting of small parts and thin delicate sections has always been a problem in metallographic practice, because mounting materials used in the past have required heat or pressure, or both, to harden them. There are, however, quite a few cases in practice which involve the preparation of sections for microscopic and macroscopic examination without the application of either heat or pressure. An attempt has been made to use casting resins of the chemical-setting epoxy type, and this attempt is reported as having met with outstanding success. Casting resins are available consisting of two liquid components, a resin and an activator. Only simple mixing and casting techniques are necessary, and the mount hardens in a few hours at room temperature. If higher temperatures can be tolerated, the time can be shortened to a matter of minutes. Separately, the two liquids are stable at room temperature but, once mixed, must be used immediately. After the casting has hardened the usual metallographic procedures of grinding and polishing can be applied. The plastic, when hardened, is highly resistant to any etchants and solvents which might be used. It would appear that many uses could be found for these resins other than the preparation of the final mount. Thus, for example, in the sectioning of thin or delicate materials, the plastic may be poured on or into the part so as to obtain a firm back-up, for the purpose of avoiding distortion in the piece during cutting. It is claimed that certain additives to the mixed liquid resin will improve its

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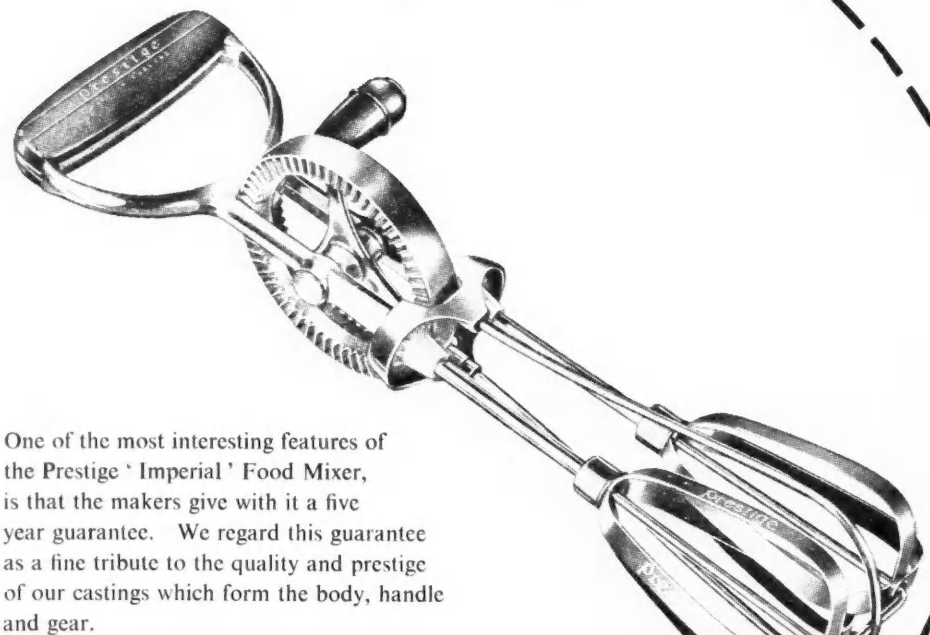
is something to be proud of



One of the most interesting features of the Prestige 'Imperial' Food Mixer, is that the makers give with it a five year guarantee. We regard this guarantee as a fine tribute to the quality and prestige of our castings which form the body, handle and gear.

Our reputation for quality and precision has brought its problems. Until a major development programme, now well advanced, is completed we may find it difficult to accept orders from new customers in spite of the fact that our output has risen by over 50% to 150,000,000 zinc and aluminium alloy pressure die castings each year.

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use as a mounting medium. Carbon black, for instance, which may be added to obtain a jet-black mount, will also help to dissipate the heat due to grinding. Various colours can be produced by the use of dyes. Carbide particles may also be inserted, to inhibit the rounding of the specimen during polishing.

● *TRANSDUCER TUBE FOR HIGH-SPEED PRINTING*

It is reported that, by means of a new type of electron image tube, high-speed printing, as required for the output of various devices such as computers, may be carried out. The tube is said to simulate typesetting by selecting letters and figures one by one from a font and placing them in luminous form on a 5-in. circular tube face in lines or any desired pattern. The font comprises a lantern-slide bearing a chart of letters and figures which are projected from outside the tube onto a sensitive layer at the rear of the tube. This photo-emissive layer emits a stream of electrons in the pattern of the projected letters. The stream is accelerated by a voltage applied to the wall coating of the tube. Selection of the letters in the required order is accomplished by means of a tiny aperture at the neck of the tube, permitting only one character at a time to pass through. The stream is shifted by a magnetic deflection coil around the outside of the tube to choose the desired letter or character. Another set of coils is provided for focusing and deflecting the character to its proper place, where it appears in visible form on a phosphor screen. Enlargement can also be accomplished by the second set of coils. It is claimed that as many as 4000 characters have been produced clearly in a single pattern on the 5-in. tube face. The typesetting process can take place at speeds up to 10,000 letters per second. In preliminary tests a perforated tape of paper was used as a source of information, but it is stated that the output of magnetic tape, wire, or radio signals, or an electronic storage unit, can also be used. In laboratory tests 2000 characters per second are reported to have been clearly recorded on a standard 35-mm film.

● *CRACK-FREE CHROMIUM-PLATING PROCESS*

A new chromium-plating process which deposits a chromium plate directly on steel and which provides much better resistance to corrosion than ordinary chromium plating has been announced. With this process the new plate is claimed to be deposited free from any structural imperfection that would allow corrosive materials to come into contact with the underlying surface to be protected. As a result, it can be plated directly onto steel, without the necessity for an undercoat of nickel, or copper and nickel. Other desirable properties of the deposit produced by the new process include a low coefficient of friction, excellent adhesion, a non-galling surface, and superior ductility as compared with ordinary chromium finishes. The crack-free deposit has an attractive light-grey dull appearance, but it can be readily buffed to a high lustre. The new plating process is carried out with a special chromic-acid type of bath having automatic regulation of the catalyst concentration. Standard plating equipment and procedure are used. The bath is prepared simply by dissolving the correct amount of a single compound in water. The same compound is used for maintenance. The bath is claimed to have good throwing power and its plating speed is said to be about the same as that of ordinary chromium. One user of the new plating process has recently installed an automatic plating machine in which shafts are plated in order to give them both chemical and wear resistance. After a 100-hr exposure to salt spray, a steel shaft plated with 0·0005 in. ordinary chromium was completely covered with rust, while a shaft plated to an equal thickness by the new process and exposed to the same conditions was practically unaffected.

● *COLOUR RADAR*

An experimental colour-radar indicator which can show planes and land areas in two colours has recently been tried out. This new indicator is built around a tube originally designed for colour television. The set produces two colours on a screen, but it is reported that a third colour could be produced without great technical difficulties. The new indicator can present any two video signals in their assigned colours. Thus, for instance, the colour set can show aircraft as bright orange dots travelling over chartreuse-coloured land areas. Also, it can be made to show aircraft at a high altitude in orange and those at a lower altitude in green. Stationary objects could be shown on the screen in one colour and moving objects in another. While the advantages of colour radar over monochrome radar have not as yet been fully established, it is claimed that colour radar will give greater visual aid to the radar operator. Modification of a standard indicator to two-colour operation would slightly increase the complexity of circuitry and would cause a slight reduction in the viewing area of the tube. The two video-input signals are electronically time-shared between successive sweeps. A fundamental feature of the new system is the utilization of two long-persistence phosphors which produce the colours. The two phosphors used in the experimental indicator yield greenish-yellow and red-orange colours, but it is expected that red and green phosphors of suitable persistence will become available. The only limitation on the number of colours which can be used, apart from the availability of suitable phosphors, is stated to be the degree of resolution required for any particular application.

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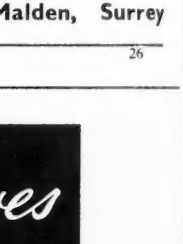

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● *WET-MACHINING OF CAST IRON*

The relatively large percentage of carbon contained in cast iron creates a brittle structure and in machining causes the metal to fracture ahead of the tool. Continuous chips are not produced and there is no need to apply the type of lubrication required by the more ductile alloys. In fact, lubricants of the type used on alloy steel can be detrimental to tool life, if used when machining cast iron. In the past it was therefore universal practice to machine cast iron dry, tool life being excellent. In recent years, however, machining speeds have steadily increased and have resulted in the creation of large volumes of fine dust, which represent a health hazard, though this dust can, of course, be removed by exhaust systems. However, in addition to the high initial and maintenance costs of such exhaust systems in plants where large-scale machining operations of cast iron are carried out, the exhaust hoods have frequently been found to interfere with tool replacement and to make machine set-up difficult. It was therefore considered desirable to evolve a method of wet-machining which would not result in a diminution of tool life. To be successful the method must employ a high wetting and dispersing water-soluble compound with special rust-inhibiting additives. It is reported that a water-soluble compound has now been developed, producing a finely dispersed emulsion which prevents oil from clinging to the chip. Its wetting properties are such that it drops the chip from the solution and allows it to settle in the tank. In addition to having rust-preventing properties, the solution has detergent properties which maintain the piping clean and keep the working areas of the machine free from mineral oil.

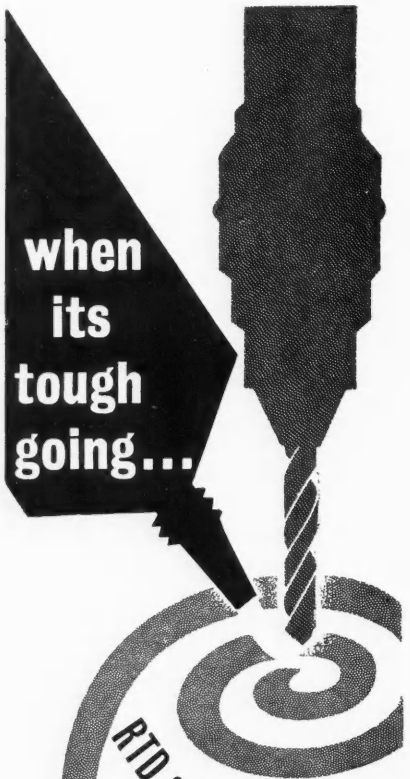
● *IMPROVED LUMINESCENT LAMP*

Luminescent lamps usually comprise a light-transmitting piece of material provided with a light-transmitting electrically conductive layer. Over this layer is placed a light-emitting coating which consists of a mixture of an electroluminescent material and a dielectric substance. On top of this coating is placed an electrically conductive backing layer. Light is emitted from the lamp when a varying voltage is applied between the conductive backing layer and the conducting surface of the light-transmitting material. The backing layer is generally quite thin and is not suitable for making permanent connections, e.g., by soldering. Moreover, any pressure applied to the backing layer will be transmitted to the light-emitting coating containing the electroluminescent material and may change its mechanical and electrical characteristics. This difficulty is claimed to have been overcome by a special design described in a recent patent specification which also gives information on the technique used in the manufacture of luminescent lamps. Of particular interest is the production of the electrically conductive layer, which must be chemically inactive with respect to the other materials used in the lamp and which must also have good light-transmitting qualities. Layers having these properties are difficult to obtain, because good electric conductors are generally good reflectors, rather than transmitters, of light. It is stated that a particularly effective layer is produced by exposing a hot glass plate to one or more chlorides of silicon, tin, and titanium, afterwards placing the treated glass plate in a weakly reducing atmosphere. Another method consists of dipping the heated glass in a boiling mixture of stannic chloride, absolute alcohol, and glacial acetic acid.

● *HIGH-STRENGTH BRAZED JOINTS*

Extensive investigations have shown that properly made butt-brazed joints with silver filler metal can develop an ultimate tensile strength four times that of the brazing metal. In consideration of the principle of adherence between metals by adsorption it was deemed desirable to avoid all base-metal and filler-metal combinations giving rise to intermetallic compounds. From a study of binary-system diagrams it was concluded that plain carbon steel and fine silver filler metal would meet this requirement. Since the surfaces to be joined must be oxide-free, a 10% hydrogen, 90% nitrogen reducing atmosphere was used instead of a flux. In order to achieve joints of minimum thickness, the surfaces were prepared by precision-grinding and polishing. However, even with these precautions oxides sometimes formed during heating, so that low strength and failure at the interface resulted. When the silver completely wetted the iron surface and the joint was sound, failure always occurred along the plane of symmetry. In this case the interface, free from diffusion and intermetallic compounds, forms an adhesion bond which is stronger than the filler metal. In the course of the investigation, it was observed that joints with a small number of voids in the filler metal—not exceeding 10% of the total area of the brazed surface—often exhibited tensile strengths as high as voidless joints. The strength of the base metal contributes greatly to the strength of the joint. Thus, with a base metal having a tensile strength of 69,000 psi, a joint of 0·00014 in. in thickness has a maximum tensile strength of 67,000 psi, while, with a base metal having a strength of 109,500 psi, a joint of the same thickness was found to have a strength of 84,350 psi.

For further information on developments reviewed in THE BLUE PAGES, readers are invited to write to the Editor.



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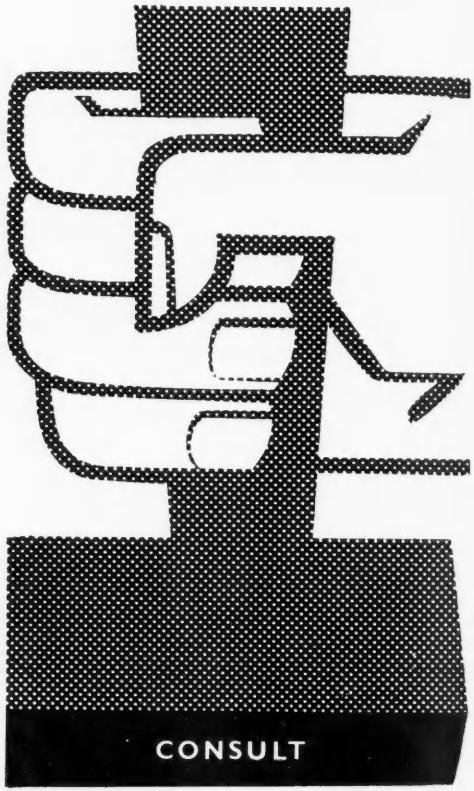

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